TECHNOLOGY REVIEW

March 1952

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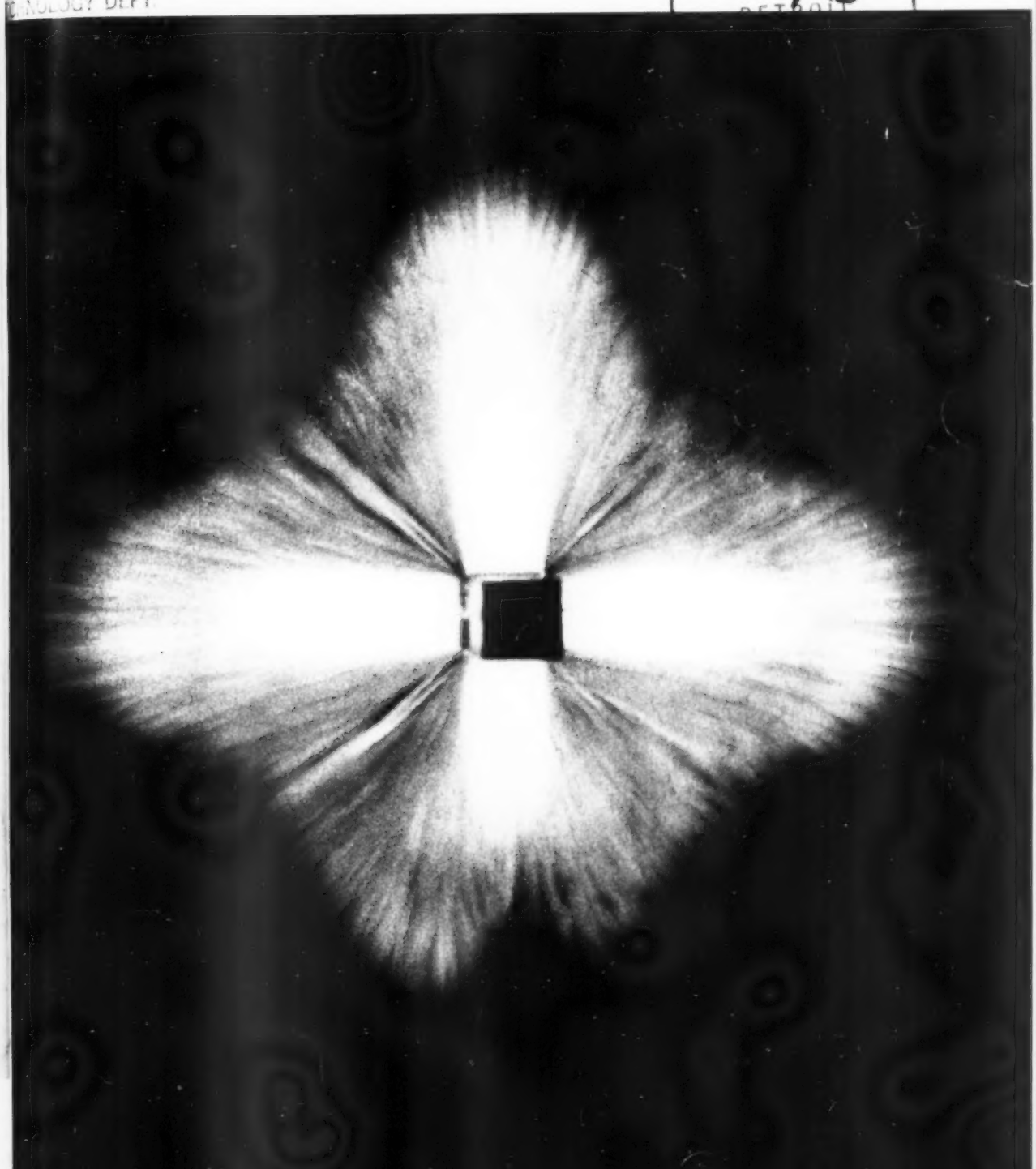
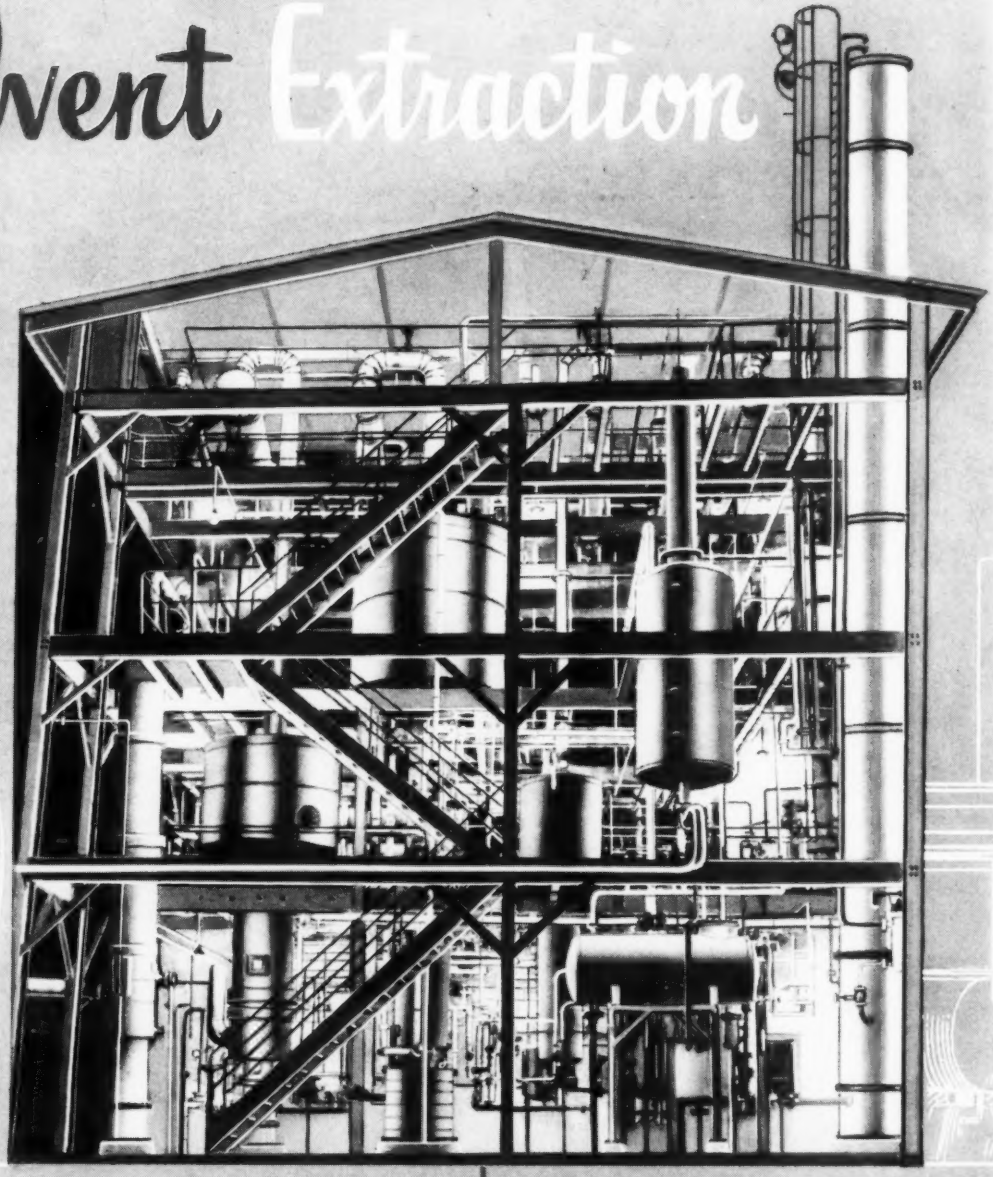


Solvent Extraction



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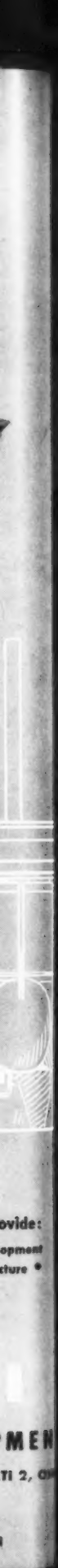

All but one of the objects in this picture have something in common — Norton or Behr-Manning abrasive products are vital factors in their manufacture and in their quality. ***Can you find the stranger?***

The sheepsfoot roller? No! Before it went to work compacting and leveling airstrips, it got its rugged strength and odd shape from processes that call for the top performance of Norton grinding wheels and refractories and Behr-Manning coated abrasives.

The organ? No! The rich finish of its woodwork comes from coated abrasive paper for which Behr-Manning is famous. Its smooth tones come from precision parts that result from the uniform grinding action of Norton and Behr-Manning products.

The ash tray? No! The entire glass industry relies on Norton and Behr-Manning abrasive products for many grinding and cutting operations.

The cigarette? No! Norton and Behr-Manning abrasives contribute in many ways to smoking enjoyment. For example, the circular blades that cut cigarettes cleanly to size are continuously sharpened by Behr-Manning abrasive discs.

The stranger in the picture is the fly. Remember, any man-made product . . . whether of metal, wood, paper, cloth, leather, ceramics or plastics . . . depends in some important way on abrasives, abrasive products, refractories or grinding machines that bear such well-known trade-marks as Norton and Behr-Manning... the world's largest manufacturers of abrasives and abrasive products.

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PREVIEWERS *of a*

ON DECEMBER 5, 1941, these utility engineers from all parts of the country made a trip to the Somerset Station of Montaup Electric Company, Somerset, Mass., to see a new boiler . . . a radically different boiler . . . a controlled circulation boiler.

The main difference between the Montaup boiler and American power boilers of conventional design was that it employed a new and different principle of circulation. Its circulation was *controlled*. With this principle, a specially designed pump is used to maintain positive circulation throughout all parts of the boiler and the flow to each section is controlled according to its needs. Conventional, or natural, circulation boilers on the other hand, depend entirely on heat to maintain circulation and do not permit positive control of flow to different circuits.

Previously, controlled circulation had been in use commercially in Europe, but only in relatively small boilers. This was the first application in an American power station and it had the further distinction of being the first boiler to produce steam at a temperature as high as 960° F. At 2000 pounds per square inch design pressure, it was also one of the two highest pressure boilers in this country.

One major advantage of controlled circulation is that it is ideally suited to use in the higher pressure range where heat as a means of circulation becomes less effective . . . and it is in this higher pressure range — from 2000 pounds per square inch up — that higher overall plant efficiencies can be achieved. There are, of course, collateral advantages such as:

- **substantial reduction in weight made possible by the use of small-diameter, thin-wall tubes;**
- **new flexibility in proportioning boilers to fit existing space;**
- **quicker starting up and shutting down;**
- **maximum number of service hours per year.**

The drastic departure from conventional practice at Montaup — which these engineers came to see — required pioneering courage as well as engineering competence of a high order to solve the many technical problems. That

C-E

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Major Development in Power Generation

Combustion Engineering—Superheater, designers and builders of the boiler, the Montaup Electric Company and the consulting engineers, Stone & Webster Engineering Corporation solved these problems has been demonstrated by the boiler's highly successful performance record over a period of years. Moreover, the proven advantages of controlled circulation have so impressed leading utility companies that they have placed orders with Combustion in the past 18 months (see list at right) representing a total investment of more than 50 million dollars. Orders have also been received from the U. S. Navy for C-E Controlled Circulation Boilers to power two destroyers of an advanced design.

• • •

The development of the Controlled Circulation Boiler is another example of Combustion's design leadership in the field of steam generation... leadership that makes it worth your while to consider C-E Boilers for your steam requirements whether large or small... utility or industrial... power or process. B-533

Utility companies that have C-E Controlled Circulation Boilers on Order

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Company	Plant Location	Capacity per unit lbs. of steam per hr.
Cleveland Electric Illuminating Co.	East Lake, Ohio	875,000
Consumers Power Company	Essexville, Mich.	1,050,000
Duke Power Company	Spencer, N. C.	900,000
Philadelphia Electric Company	Chester County, Pa.	1,450,000
Public Service Electric & Gas Co.	Kearny, N. J.	1,015,000
Southern California Edison Co.	Etiwanda, Calif.	920,000
Virginia Electric & Power Co.	Wheelwright, Va.	750,000
	Gilmerton, Va.	750,000
Wisconsin Electric Power Co.	Milwaukee, Wis.	795,000

—SUPERHEATER, INC.

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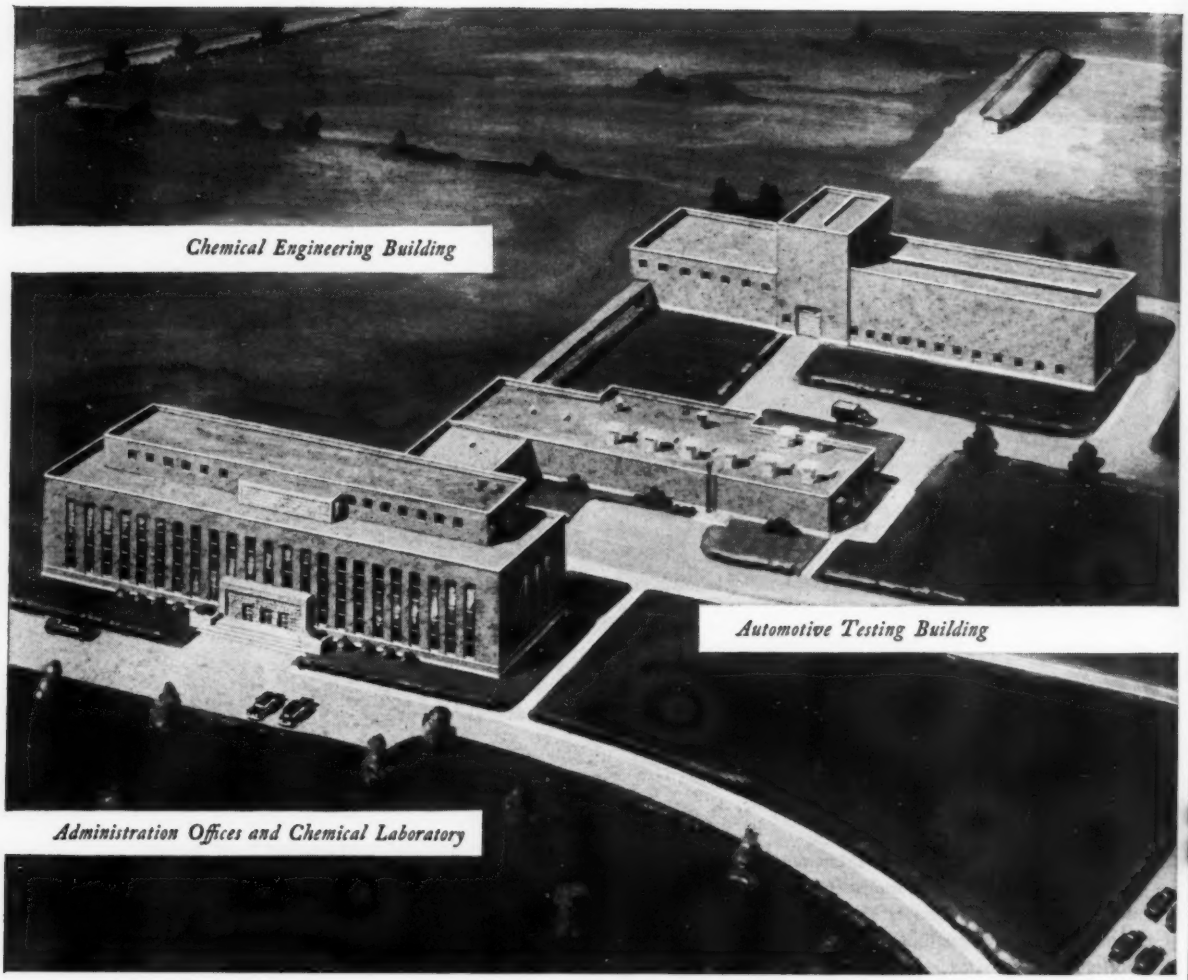
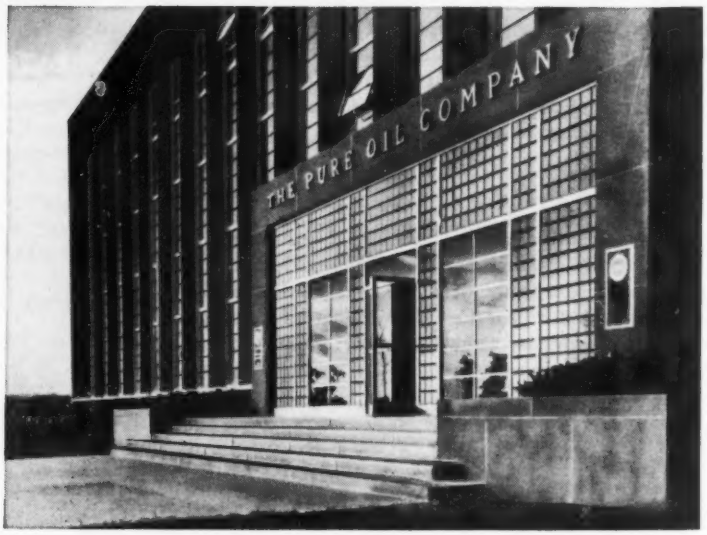


Crystal Lake LABORATORY

When Pure Oil Company considered building a Research and Development Laboratory at Crystal Lake, Illinois, Stone & Webster Engineering Corporation was engaged to make preliminary studies and estimates. It later designed and furnished engineering supervision during the construction of the project.



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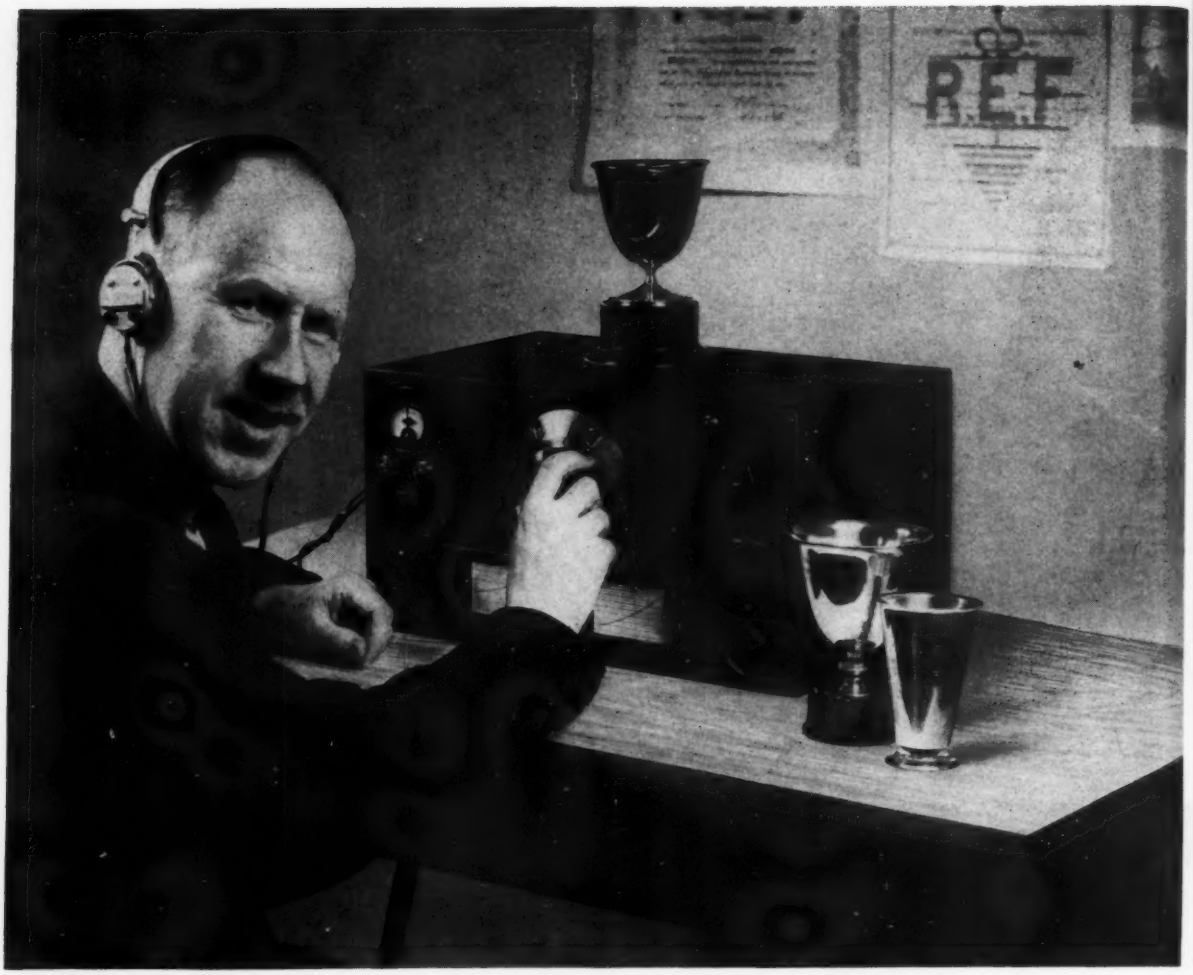

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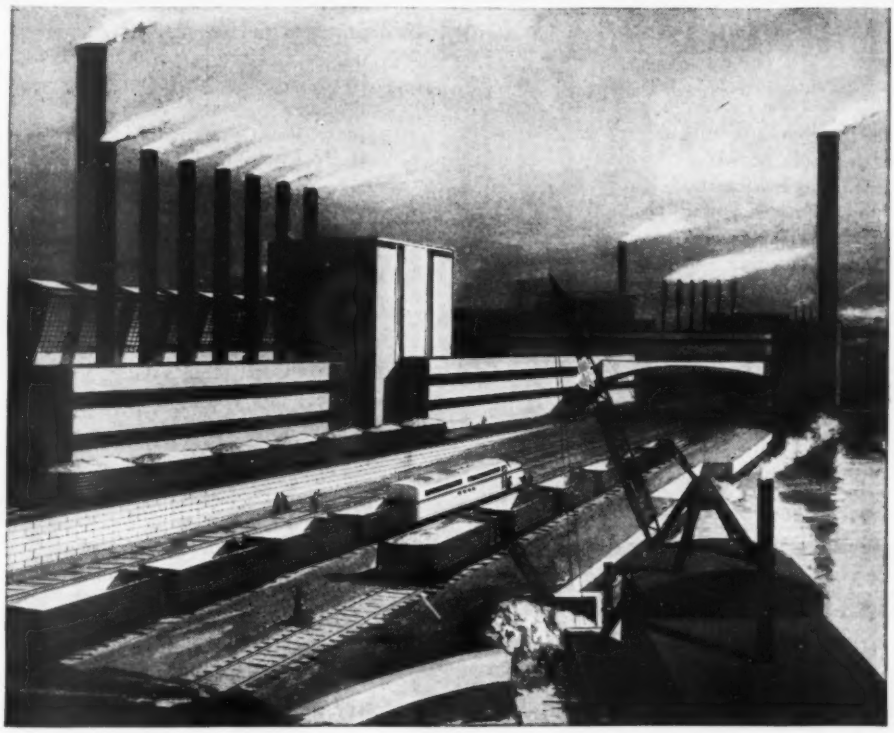

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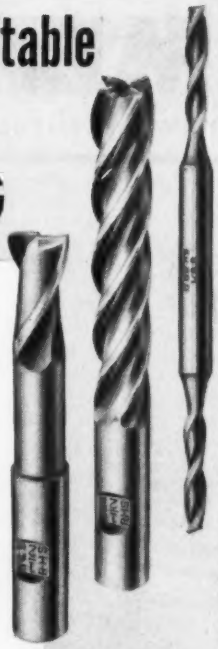

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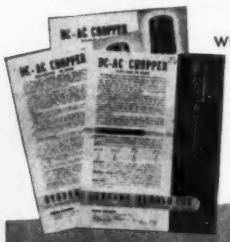

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THE TABULAR VIEW

Future. — Uncertainty accompanies any prophecy, but forecasts of events which may be expected to occur as much as a quarter of a century in the future are in a particularly precarious state. That the role of prophet is an unenviable one is clearly recognized by PROFESSOR JOHN B. WILBUR, '26, whose imaginative vision enables him to discern (page 235) what may be in store for us two or three decades hence, as the result of progress in civil engineering. Although second only to military engineering in seniority, civil engineering is not the quiescent, staid branch of applied science which many suppose it to have become because of age. As a matter of fact, as Professor Wilbur points out, fundamental research now in progress in this field brings to civil engineering a new vitality and activity which is nonetheless significant even if not too widely recognized. As consulting engineer with Fay, Spofford, and Thorndike, of Boston, in addition to his post as Head of the Department of Civil and Sanitary Engineering at M.I.T., Professor Wilbur is eminently qualified to discuss trends in civil engineering. He holds three degrees from the Institute and since 1930 has trod the traditional academic steps from instructor to head of a Department at M.I.T. Dr. Wilbur's article represents the text of an address given before members of the student branch of the American Society of Civil Engineers. The informal, somewhat humorous vein in which the article is written embraces a good deal of sagacity presented as coming from the mouths of alert Faculty members. Illustrations for this article are from the drawing board of Henry B. Kane, '24.

Past. — The steady march of daily progress occurs so gradually that it is only in retrospect that significant changes come into true focus. We have been witnessing the tearing up of streetcar tracks for many years now without being much concerned about the social and technological changes which such action makes in our way of life. The full impact of such evolution is ably discussed (page 240) by HENRY BOWEN BRAINERD, born in Wellesley in 1907, graduated from Harvard in 1929, and now a staff member of the Institute's Instrumentation Laboratory where he is working primarily on problems of applied mathematics. Mr. Brainerd's hobby is streetcar railroading and, with the love of a true amateur, he has served (from 1940–1951) as chief engineer, and is now vice-president of the New England Electric Railway Historical Society. At Kennebunkport, Maine, this active and ambitious organization is building an operating museum of trolley cars, called the Seashore Electric Railway. It is from his all-absorbing avocation – and from co-operating members of the N.E.E.R.H.S. – that Mr. Brainerd obtained the material for his historical survey of streetcar transportation, including the timetables, maps, fare data, and local coloring mentioned in the imaginary trip from Needham to West Brookfield, Mass. All aboard! Ding! Ding!

(Concluded on page 226)

What do you know about MoS_2* as a lubricant?

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THE TABULAR VIEW

(Concluded from page 224)

Present. — Hundreds of millions of dollars are spent each year in the machine-tool industry for operations which, at best, have an empirical basis and are, accordingly, imperfectly understood. In recent years the potent tools of scientific observation and analysis have been applied to a number of the more essential and fundamental operations in this field. As a result, a renaissance in metal cutting is taking place, according to MILTON C. SHAW, Associate Professor of Mechanical Engineering, whose article in this issue (page 245) outlines significant research at the Institute. Professor Shaw's undergraduate training in mechanical engineering was received at Drexel Institute of Technology, from which he received the B.S. degree in 1938. During the next four years he was Cincinnati Milling Machine fellow at the University of Cincinnati where basic work in chemistry, physics, and mathematics was taken, leading to the degree of doctor of science in 1942. In 1946 Professor Shaw joined the teaching staff of the Institute. Since 1950 he has been in charge of the Machine Tool and Metal Cutting Division of the Department of Mechanical Engineering.

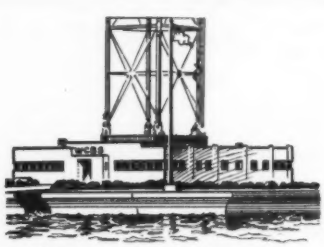
MAIL RETURNS

Pardonable Pride

FROM RALPH LOWELL:

I have read with a great deal of interest the copy of the December, 1951, Review containing the article "The Lowell Institute School" by Arthur L. Townsend. I am proud of the school we have at your good institution and appreciate all the work Professor Townsend and his Faculty do in its behalf.

Boston, Mass.



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Acetylene is the source of some of the basic chemicals in *dynel*, the new wonder textile fiber. It also goes into the Vinylite plastics used in beautiful home furnishing materials, protective coatings, and a host of other products.

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GOODYEAR

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Henry Frank from Black Star

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THE TECHNOLOGY REVIEW

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CONTENTS *for March, 1952*

Vol. 54, No. 5

PENTOLITE PENTAGON • *Photograph by Aberdeen Proving Ground* THE COVER

Explosion of a ¾-inch square stick of pentolite photographed by means of the Faraday shutter developed by Harold E. Edgerton. Exposure time was five microseconds

END OF THE LINE • *Photograph by Ward Allan Howe* .. FRONTISPIECE 230

WHITHER CIVIL ENGINEERING? ..... By JOHN B. WILBUR 235

Stark realism and fancy are combined to present a picture of the way in which civil engineering will have remade our living 25 years hence

STEPBROTHER TO THE IRON HORSE ..... By HENRY B. BRAINERD 240

Having played a noteworthy part in surface transportation, the streetcar trolley joins the American buffalo as a symbol of a bygone era

RENAISSANCE IN METAL CUTTING ..... By MILTON C. SHAW 245

When the analytical techniques of science replace the skilled empiricism of the craftsman in a field as basic as metal cutting, something is bound to happen

THE TABULAR VIEW • *Contributors and Contributions* 224

MAIL RETURNS • *Letters from Review Readers* 226

THE TREND OF AFFAIRS • *News of Science and Engineering* 231

THE INSTITUTE GAZETTE • *Relating to the Massachusetts Institute of Technology* 248

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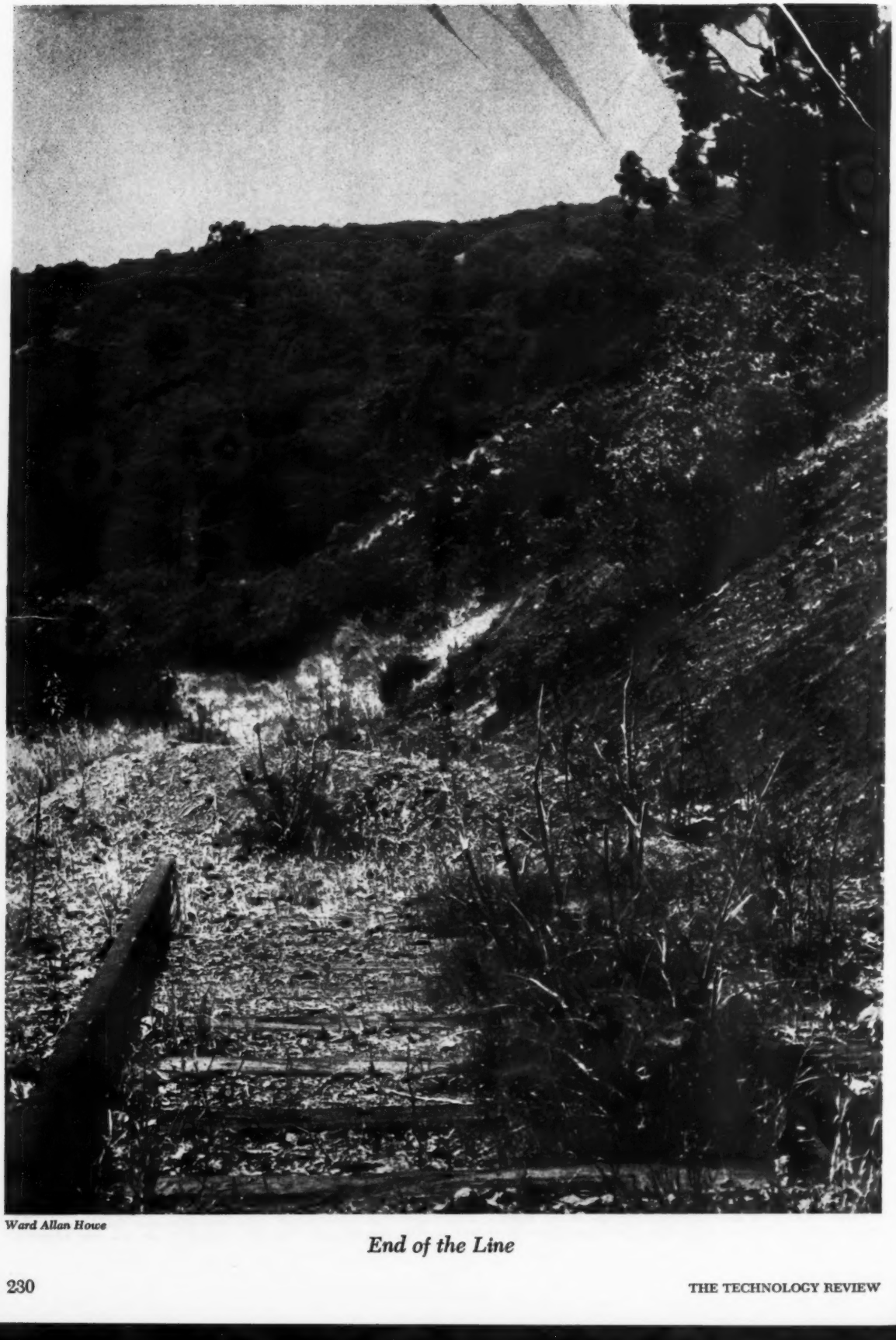


Ward Allan Howe

End of the Line

THE

TECHNOLOGY REVIEW

Vol. 54, No. 5

March, 1952

The Trend of Affairs

Packaged Protection

In present-day food markets, nearly all foods sold in the United States are retailed in packages which are usually convenient in size, attractive, functionally protective, and easy to open. For many years dried or partially dried foods have been sold in packages, but now it is rapidly becoming common practice to retail, in prepackaged form, fresh fruits and vegetables, fresh and cured meats, fish, and other sea-food products. In comparatively recent years food packages have become indispensable to our way of life. The trend toward the establishment of large supermarkets and progress in the field of frozen foods have both contributed in large degree to the expansion of the prepackaging industry, for protective and attractive packaging has proved a stimulus to sales.

Technological progress in food preservation in the relatively new field of food technology has also been a stimulus to the packaging industry. The development of many new types of foods, particularly of dried and of frozen foods, has been responsible for considerable research and progress in packaging. World War II was responsible for great advances in protective packaging for food rations, such as the K ration. These ration packages were required to withstand all kinds of temperature and humidity, in addition to rough handling. The packaging technologist has worked hand in hand with the food technologist in all these advances.

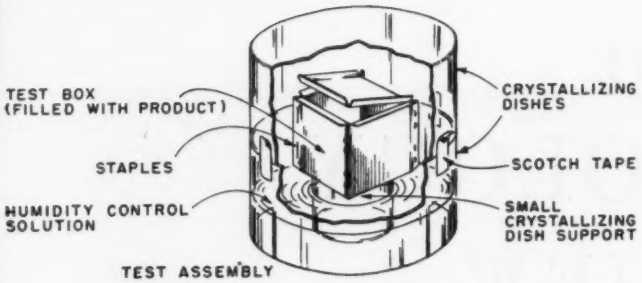
In the Department of Food Technology at the Institute, research has been under way since 1946 in the field of food packaging technology. This program has been conducted by Arthur H. Landrock, '49, a technical assistant in the M.I.T. Department of Food Technology, under the supervision of Professor Bernard E. Proctor, '23, Director of the Samuel Cate Prescott Laboratories of Food Technology. The major aim of the program has been the development of new and improved test methods for studying the characteristics of both food products and packaging materials, methods which, it is hoped, may ultimately be accepted as official procedures for industry.

A method recently developed by the Department as a result of this program permits the rapid determination of the equilibrium relative humidity of foods and food products; that is, the relative humidity at which the substance neither gains nor loses moisture under given temperature conditions. This method, called a "graphical interpolation method," is less complicated than other methods which have been used to yield the same data.

According to the graphical interpolation method, uniform amounts of a given food product of a given moisture content are exposed to controlled atmospheres of different relative humidities for the same period of time (usually one hour) at a constant temperature. The gains or losses in weight by the samples are determined, and these values are plotted against relative humidity, with the gains appearing above and the losses below a "zero base line." A smooth curve is drawn through the plotted data, and the equilibrium relative humidity is interpolated at the point where the curve intersects the base line. These steps are repeated for the same product at several other initial moisture contents.

This method for measuring humidity equilibriums has been found applicable to any type of food product, whether powder, solid, liquid, or heavy syrup. It has the advantage of enabling considerable savings in time because of the simplicity of technique.

The attractiveness of a package depends in part upon the grease resistance of the packaging material. The degree of grease resistance required is governed by the free oil or fat in the food product to be packaged. If the packaging material is not sufficiently grease-resistant, the free oil may cause undesirable stains. On the other hand, if the packaging material offers more protection than is necessary, the cost of the package will, obviously, be unnecessarily high.



The diagram above shows the construction of paper boxes used in determining the oil-staining properties of foods.

Up to the present, methods used for comparing products on the basis of their free oil content have been extremely crude. To provide the food industry with a suitable method for measuring the ability of a food product to release oil or fat to stain a package, a quantitative method of measuring free oil has also been developed. Given weights of foods are stored under controlled conditions of temperature and humidity in standard, stapled, test boxes made from high-grade photographic blotting paper. After 48 hours, the amount of oil transferred from the food to the box is determined by petroleum ether extraction, and is expressed in terms of milligrams of fat extracted per gram of food. Recommended standard conditions are a temperature of 100 degrees F., relative humidities of 30 per cent and 90 per cent, all samples being of the same weight and filling the box shown at the left. Ether extraction periods of only three hours were found to be sufficient.

Eighteen representative food products have been studied under these conditions. The amount of free oil absorbed by the test box was found to be about twice as much at a relative humidity of 90 per cent as at 30 per cent. Tests made with piecrust mixes of different fat contents indicated a logarithmic relationship between free fat and total fat content.

The combination of available quantitative data on the free oil content of foods and the degrees of grease-resistance of packaging materials should enable manufacturers to package their oily products more satisfactorily.

Present research activities of the Department in the field of packaging include a new method of measuring simultaneously oxygen and carbon dioxide permeabilities of packaging materials, a method for measuring flavor and odor permeabilities of packaging materials, and a study of the effect of multiple components on the equilibrium relative humidity of mixtures of crystalline materials.

Plastic Boats

Among the new materials to enter the field of small-boat construction, none appears more promising than the glass-reinforced polyester laminates. These tough, strong plastics have tensile strengths in the order of 30,000 pounds per square inch and higher, and a resistance to impact that bears comparison with that of many structural metals. An illustrative application is that of a tie plate for railroad use, made of glass-reinforced polyester resin, and now undergoing service tests on the Erie Railroad. This plate, about one-foot square, is placed between rail and wood tie, and absorbs and distributes the loads of trains passing over the rail. The plastic plate is proof against corrosion, which is the greatest enemy of the standard steel plates, and has about one-quarter the weight of the steel. Since American railroads purchase about 40,000,000 tie plates per year, this is no small matter. Numerous other structural applications of these laminates, particularly in airplanes, also exist.

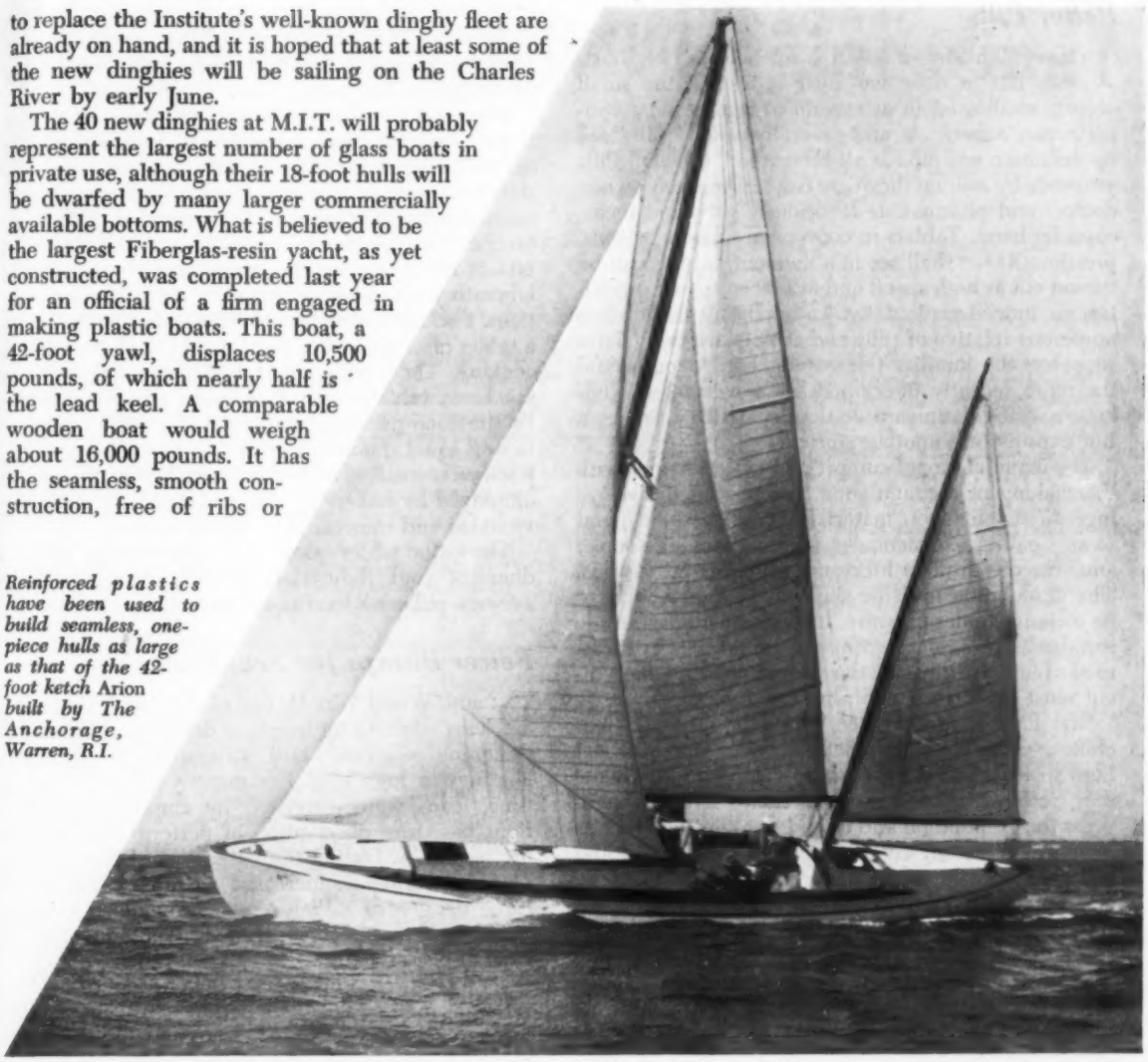
This same type of reinforced plastic is competing vigorously in boat construction with steel, aluminum, plywood, and laminated wood. The last two materials, of course, are also tributes to the plastics, since their utility in marine environments is due to water- and weather-proof bonding agents of synthetic resins. Unlike iron and aluminum, which have long been used in ship construction on large hulls, and which only lately have begun to appear frequently in smaller craft, the glass-resin laminates were first tried in the very smallest craft, such as rowboats and dinghies. Here mold costs were lowest, and less was at stake if the design proved faulty. Up to the present time, it is safe to say that the bulk of the production has been in boats under 15 feet in length. The toughness and durability shown by these craft, the reduced problems of upkeep, the relative ease of repair, and the inherent possibilities of their production processes for large-volume production, have created a marked trend toward the development of much larger plastic hulls. The Coast Guard has reported that repairs to plastic hulls possess at least 70 per cent of the strength of the original hull.

Although most of the larger designs are being built generally in prototype form for the military, small-boat owners can now buy standard plastic hulls up to about 24 feet long. In this connection it is interesting to learn that the fleet of dinghies, in constant use at M.I.T. since 1936 (and which now show signs of such wear as to make repair and maintenance a major problem) will be replaced this year. The new fleet will be similar to the original, except that Fiberglas will replace wood, and only such modifications will be made in the hull as are required to use the newer plastic process. The older boats, designed by Professor Emeritus George Owen, '94, of the Institute's Department of Naval Architecture and Marine Engineering, have given universal satisfaction, according to Walter C. Wood, '17, Sailing Master at M.I.T. Sample glass boats which have been tested on the Charles River, have been found entirely seaworthy and show every promise of meeting the rigorous demands of a collegiate dinghy fleet.

The glass-plastic hulls for the new dinghies can be obtained for the same cost or less than that necessary to build the fleet with wood, and there are good indications that repairs and maintenance will be less with the glass-plastic boats than with their wooden counterparts. A substantial portion of the funds required

to replace the Institute's well-known dinghy fleet are already on hand, and it is hoped that at least some of the new dinghies will be sailing on the Charles River by early June.

The 40 new dinghies at M.I.T. will probably represent the largest number of glass boats in private use, although their 18-foot hulls will be dwarfed by many larger commercially available bottoms. What is believed to be the largest Fiberglas-resin yacht, as yet constructed, was completed last year for an official of a firm engaged in making plastic boats. This boat, a 42-foot yawl, displaces 10,500 pounds, of which nearly half is the lead keel. A comparable wooden boat would weigh about 16,000 pounds. It has the seamless, smooth construction, free of ribs or



Reinforced plastics have been used to build seamless, one-piece hulls as large as that of the 42-foot ketch Arion *built by The Anchorage, Warren, R.I.*

stiffeners, characteristic of molded boats, and a hull thickness that varies, as required, from about one-fourth inch to about one inch thick.

Since the Navy, Coast Guard, and Army have need of many types of small boats, some of which have to be produced in large numbers on short order, they have been particularly interested in this development. To insure that the plastic hulls will be able to stand up under the very severe service that such craft must frequently endure, the services on a number of occasions have built hulls to substantially the same lines in plastic, plywood, laminated wood and metal, and are in the process of long-time tests under actual conditions of operation to determine relative merits. Among the various types, so far produced, are: a 12-foot wherry, a 21-foot rescue boat for shallow water (propelled by a water jet); a number of lifeboats, about 26 feet long; a 36-foot L.C.V.P. (landing craft) which has already been produced in five slightly differing versions and which may undergo large-scale production; and a 40-foot general utility boat which the Coast Guard has also built in plywood, laminated wood, and steel.

A contract has been placed for the construction of two prototype mine sweepers in glass-resin laminate. These boats are intended for shallow water and harbor work, and will be 57 feet long with a 15-foot beam. Of lightweight laminates, these vessels will displace 30 tons.

While plastic laminates can be made with a wide variety of plastics and reinforcing materials, there is a growing tendency to consider this phase of the plastics industry in terms of the polyester resins with fibrous glass reinforcement. The production of polyester resins was reported to be between 8,000,000 and 9,000,000 pounds in 1950, and with it was used some 4,000,000 to 5,000,000 pounds of fibrous glass. In 1951, polyester resin production rose to over 13,000,000 pounds, and glass fiber consumption, in this field, to more than 7,000,000 pounds. Expansion in both resin and glass fiber productive capacity is continuing at a steady pace.

Better Pills

TODAY pillmaking is an art, a science, and big business. But at once we must state that the small objects swallowed in astronomical numbers by contemporary Americans, and generally called "pills," are by definition not pills at all but rather "tablets." Pills are made by rolling; they date from former days when doctors and pharmacists laboriously prepared medicines by hand. Tablets in contrast are made by compression. As we shall see in a moment, tablets can be turned out at high speed and at low cost; vast quantities are indeed made daily. An important though less numerous relative of pills and tablets are the gelatin capsules; the familiar telescoping hard capsule and the more recently developed but nevertheless well-known, soft gelatin capsule that looks like a tiny egg. But capsules are another story.

The manufacture of compressed tablets begins with the making of a granulation, comprising the active ingredients plus inert materials (starches, sugars, and so on) called excipients, and sometimes also small amounts of harmless lubricants, such as fatty acids. The granulation must be skillfully designed so as to be cohesive under pressure. Its bulk must be carefully standardized, as the portion for each tablet is measured volumetrically, yet the weight of active ingredient must be correct within narrow tolerances.

The finished granulation is fed to tableting machines, completely automatic devices operating at high speed. Here the granulation is filled into hollow dies, into which plungers are then driven to compress the granulation and unite it into finished tablets in a single stroke. By merely varying the die and plunger, tablets may be made in almost any desired size and shape. Either surface or both may be imprinted with lettering, or a trade-mark, engraved in reverse on die or plunger.

The manufacturing technique described is aimed toward accomplishment of two diametrically opposite objectives. The tablet must, on one hand, be sufficiently cohesive and sturdy to be unharmed by packing, shipping, and handling by the consumer. Yet, on the other hand, it must disintegrate and release its active ingredient almost instantaneously when swallowed, dropped into water, or however used. Skill in designing the granulation and in adjusting the tableting pressures achieve these aims. Accurate regulation of the bulk of the granulation, of the ratio of active to diluting ingredients, and of the volume of granulation compressed into each tablet effects exact control of the concentration of active ingredient per tablet. Thus doses can readily be made with accuracy as small as a few milligrams per tablet.

Compressed tablets are often distributed exactly as they emerge from the tableting machine. The familiar aspirin tablet is of this sort. Or art may join science for beautification by coating, coloring, or polishing.

Coating is done with sugars, in rotating pans such as are used to coat chewing gum and other confections. During the coating any one of a rainbow of harmless food colors may be incorporated. Tinting has a minor purpose in making the tablet pretty, but serves an important function of identification even if tablets become separated from label containers. Such positive identification is most important, for example, in hospitals. As a touch of high art, coated tablets are often given a brilliant gloss with wholesome waxes, again in rotating pans.

Although the most familiar application of tablets is for administration of medicines, vitamins, and so on, by mouth, tablets are useful wherever a dry substance needs to be conveniently handled in accurately measured, small amounts. Thus a number of disinfectants and germicides are supplied in tablet form, and tablets are made for the convenient preparation of laboratory solutions of precisely known concentrations. Packages of prepared lemon-pie filling contain a tablet of citric acid to be added in the home during cooking. Those who count their calories may drop saccharin tablets instead of sugar into their coffee. In the food-packing industry, salt tablets are used to add exact quantities of salt to cans of vegetables just before sealing and sterilizing. Jumbo tablets are employed by bakers to add to doughs the necessary vitamins and minerals for enriched bread.

Thus the tablet plays a larger role in modern domestic and industrial economy than even the average pill swallower is apt to realize.

Fewer Bumps for Seaplanes

DURING World War II, one of the perplexing problems confronting seaplane designers, was that of designing seaplane hull structures to withstand landings in high seas. For many years prior to this time, loads were estimated by empirical specifications based on observation of performance of existing seaplanes. During the latter part of the war, seaplane performance increased so rapidly that it became dangerous to rely on a design load criterion based only on past experience. Consequently, the Bureau of Aeronautics, Navy Department, undertook several research programs for the purpose of devising rational methods of predicting seaplane landing loads. One of these programs emphasizing the fundamental aspects of the phenomena of impact was carried out in the Department of Aeronautical Engineering by Raymond L. Bisplinghoff, Associate Professor of Aeronautical Engineering and Carl S. Doherty, '48, of the Division of Industrial Coöperation staff.

This program combined theoretical and experimental studies of the impact of two dimensional wedges with special emphasis on the shape of the free water surface as the wedge penetrates the water. Experimental studies of the shape of the free water surface were made by high-speed photographs of the piled-up water adjacent to the entering wedge during crop tests. The studies concluded that certain easily applied impact theories can predict the shape of the piled-up water and the force-time history during impact with satisfactory degree of accuracy. In addition, methods were indicated of relating the shape of the force-time curve during impact to the cross sectional shape of the wedge. Such methods may be of value to seaplane designers in lessening impact loads. It is believed that these fundamental studies of the phenomena of impact of wedges on a water surface have produced a better understanding of loads on seaplane hulls during rough landings.

Whither Civil Engineering?

By JOHN B. WILBUR

Anyone who gazes into a crystal ball will probably find the trouble which prophecy invariably invites. Professor Wilbur does not expect everyone to agree with his long-range forecasts, especially since he does not necessarily believe all of the predictions which are, presumably, made by members of the Department of Civil and Sanitary Engineering. Incidentally, Professor Wilbur absolves members of the staff of his Department of any responsibility in connection with their "quoted" remarks.

The accompanying article represents the text of an address given at a meeting on December 11, 1951, of the student chapter of the American Society of Civil Engineers to which first-year students in Civil Engineering were invited. To be sure, the prophetic manner of presentation serves to stir the imagination of budding civil engineers, but it does more than that. It demonstrates rather forcefully that civil engineering — now in the transition between empiricism and rationalism — is a dynamic branch of engineering heavily dependent on basic science and a wide range of research programs already in progress.

Possibly Professor Wilbur had his tongue in cheek in making some of the prophecies in this article. Nevertheless, those with a flair for looking beyond their noses can derive stimulation from a bit of fancy which — when the period of forecast has expired — may well prove to have fallen far short of its mark. — Ed.

WHEN I was asked to give this talk on the future of civil engineering, I had some hesitancy as to the wisdom of accepting the invitation. It takes a brave and possibly a foolhardy man to peer into the unknown, and since I am not particularly brave, and I hope not too foolhardy, I should probably have felt it necessary to decline if it had not been for one thing, namely, the presence on the staff of our Department of an exceptionally able group of researchers.

I am afraid that during the past month some of you have at times found it difficult to get into my office to discuss such weighty matters as whether or not I would permit you to drop fluid mechanics and substitute an easier subject. When Mrs. [William F.] Powers, my Secretary, told you that I was "in conference" you may have thought that I was probably either doing some consulting work or taking a nap. But such was far from the case.

The fact is that I had called together a group of our professors and put the matter squarely up to them. We needed a crystal ball, and we needed it by the morning of December 11, at the latest. We organized a research team, and appointed Henry M. Paynter, Jr., 10-44, Assistant Professor of Hydraulic Engineering, as project leader. We were in conference for as much as 18 hours a day for over a week, each of us bringing to bear all that his special knowledge could contribute to the problem. Professor Paynter had been given the grave responsibility of project leader because it was believed that in his electronic analyzer for nonlinear systems[1] he had already developed a device that more nearly approached being a crystal ball than anything else in the Department. Arthur T. Ippen, Professor of Hydraulics, was a member of the team because we thought that the hydraulic analogy to the supersonic flow of air[2] might have something to do with the problem; Murray P. Horwood, '16, Professor of Sanitary Science, because it appeared hopeful that ultrasonic vibrations might have some effect on the future as well as on bacteria.[3] Rolf Eliassen, '32, Professor of Sanitary Engineering, was a key member because it was unthinkable that any serious work could proceed on an ultramodern project without mixing in a few radioactive isotopes,[4] while Robert J. Hansen, '48, Associate Professor of Structural Engineering, who had just returned from Operation Greenhouse in the Marshall Islands,[5] played a vital role in connection with those phases of the problem involving the blast of A-bombs. I must not neglect to mention the contribution of Thomas W. Lambe, 2-44, Assistant Professor of Soil Mechanics, whose last-minute solidification by chemical methods,[6] of the quivering object assembled by our team, converted it into a stable and usable mechanism, nor indeed the genius of Herman J. Shea, '33, Associate Professor of Surveying, whose immense knowledge of optics was instrumental in leading us to the conclusion that at least a portion of the surface of the ball should be constructed of a transparent material; and I cannot overstress the importance of this, since otherwise we could not have seen into the ball after it was completed.

[1]Research project on "Transient Stability of a Nonlinear System" for Research Corporation.

[2]Research project on "Hydraulic Analogy to Supersonic Flow of Air" for Air Force.

[3]Research project on "The Biology and Biochemistry of the Zooglea Producing Organisms Involved in the Activated Sludge Process" for National Institute of Health.

[4]Research project on "The Efficiency of Present Water Treatment Methods in Removing Radioactive Substances from Water" for Atomic Energy Commission.

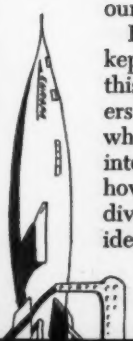
[5]Research project on "Pacific Tests" for Corps of Engineers.

[6]Research project on "Solidification of Soils in the Field of Chemical Agents" for Corps of Engineers.

I hope I have given proper credit to all those who contributed to this miraculous venture, for there is certainly enough credit to go around. In any event, under the dynamic leadership of Professor Paynter, the crystal ball was not only built, but it was completed 12 hours ahead of a seemingly impossible construction schedule, and even more important, it actually worked. I shall never forget Professor Paynter's telephone call of last evening, asking me to come back to the Institute to see the completed brain child of this astounding group. Once again it had been demonstrated that in research, as in other endeavors, the teamwork of first-class minds can accomplish the practically impossible.

Naturally our first concern was to determine whether or not the pictures of the future as seen in the Paynterscope (for by this time we had named the crystal ball after the man whose genius had, more than that of any one else, been responsible for its development) were authentic and reliable. This was a difficult thing to determine, since there appeared to be no foreseeable events in the future against which we could calibrate the device for accuracy. In this dilemma, Professor Shea once again saved the day. At his suggestion the time scale was set at 50 years ago last summer, and the space scales set on the latitude, longitude, and elevation of our summer surveying school, Camp Technology. Fortunately, the Paynterscope caught the camp on a clear day, and the boys were all out on stadia work. The picture was so clear that Professor Shea could read the instrument numbers on the transits. Since most of these instruments were still in use at camp, he was able to identify them, and this proved, to his satisfaction at least, that our device registered accurately on the negative time scale. On this basis he argued that, by extrapolation, we were justified in trusting the positive time scale, particularly since as long as we used the Paynterscope to foretell the distant future (which after all was of greatest interest) we wouldn't be around to be blamed if it eventually proved that our forecasts were incorrect. The logic of this argument was indisputable, and accordingly at quarter of eleven last night, a moment that will surely be recorded in scientific history, the time scale was set at 25 years into the future. With Professor Paynter at the controls, Mrs. Powers taking notes, and the rest of us gazing in wonder at the screen of the Paynterscope, we were away on our exciting journey into the future!

If I look haggard this evening, it is because we kept glued to the Paynterscope until the bells rang this morning for our nine o'clock classes. Mrs. Powers has spent most of today typing up her notes of what we said, so there hasn't been time to put them into very good shape for tonight's talk. They have, however, been arranged according to the different divisions of civil engineering, and the speaker is identified by initials for each statement recorded.



It is difficult to know where to begin, but since it all happened because we were transported 25 years into the future, let's start with transportation engineering. I'll have to follow my notes pretty closely on this:

J.B.B.* Look! What a relief! They've still got railroads! But what's that long thing that looks like a caterpillar stretching across the state of Ohio?

A.J.B. It's a conveyor belt. Looks like they're hauling ore to the Great Lakes.

T.W.L. Hold it! Let's look at that open field again! I thought so! It's an airport now! They've just sprayed it with calcium acrylate!

A.J.B. Let's tune in on Boston. I want to see how the traffic situation is. Say, look at those cars go! They've really gone to town on those superskyways! And look at all those multistory parking garages! No more parking on the streets!

J.B.B. And look how they've developed the subway system and the big parking areas at their terminals in the suburbs! That's certainly keeping a lot of cars out of the city!

A.J.B. I see they've added another tube to Sumner Tunnel and the East Boston skyway's still there. Let's look at the airport.

R.J.H. It isn't an airport any more; it's a rocketport now. Look at those launching devices for the transatlantic rocket ships! What's that big one at the far end of the field? The sign says: "Restricted — Operation Polaris"! I wonder what that is?

A.J.B. Did you see the terminals of all those pipe lines? I noticed that they had a lot of pipe lines all through the Middle West. I guess most fluids are being carried that way.

J.B.B. They'll never put the railroads out of business!

A.J.B. Maybe not, but look at those trailer trucks! I guess they've grabbed most of the interurban business! No wonder! Look at all those superhighways! Aren't they beauties? All dual lane and limited access. Looks, too, like they've gone in for black-top in a big way — at least here in New England.

T.W.L. That isn't black-top, Professor, it's calcium acrylate!

J.B.B. No, it isn't. It's rubber!

A.J.B. That's utterly impossible! Why, just last week I proved conclusively that it would never be economically feasible to surface roads with rubber!

*See reference key at end of article, page 260, for full names and titles.

J.B.B. Maybe so, but there it is! What I want to know is: where did they ever get all the civil engineers to build all these things?

A.J.B. And where did they get the money?

Before leaving the subject of transportation engineering, I would like to add a few comments of my own. It was apparent that the spheres of operation for the different modes of transportation were becoming more clearly defined. Thus the long haul of heavy solids (with the accent on speed), was dominated by the railroads on land and by ships at sea, while the long haul of fluids, especially on land, was accomplished by pipe lines. For the long haul of passengers and of lighter goods, air transportation held practically a monopoly whether over land or sea. For shorter hauls, however, whether of heavy goods, light goods or passengers, the motor vehicle led the field, with two important exceptions: namely, the transportation of heavy solids by conveyor belts along lines of exceptionally heavy traffic, and of passengers by rapid transit systems in congested areas.

This clarification of function, together with applications of new technological developments, had led to transportation that was not only faster and more comfortable, but most important of all, less expensive. This had contributed effectively to raising the standard of living, not only because it reduced the cost of the distribution of goods, but because better transportation, together with better systems of communication, made it practical to co-ordinate business and industrial activities at locations some distance from each other. This had added momentum to the current trend toward decentralization of our cities, with the result that more people could live, work, and play in areas that were less congested. And behind all this, the civil engineer played the important role of providing the basic ground facilities for transportation — a service so vital that it touches on every sphere of human endeavor.

But let's get back to the Paynterscope and my notes, in which the next general heading is Hydraulic Engineering:

A.T.G. Look at that string of hydro plants along the Connecticut River! You wouldn't think there was enough head on them to make them pay!

J.W.D. More efficient hydraulic turbines and hydraulic structures — that's the answer; not so much lost head. They're using the water to better advantage. I guess they have to. After all, the supply of water is limited.

A.T.I. That's why there's so much emphasis on multipurpose river development. It isn't just power. Look how they're combining power, flood control, irrigation, water supply, and to some extent navigation.

H.M.P. There's an atomic energy plant. They're generating nuclear power as a by-product, but nuclear power doesn't seem to be too important in the whole power picture.

A.T.G. No, it's too expensive. It's used more for special applications where price is secondary — submarines, for instance. It hasn't had much effect on water power. Did you notice how they're diverting water from one drainage basin to another? They don't seem to think anything of that, do they?

J.B.W. Or of backing up their hydro plants with wind power. Did you see those batteries of wind turbines all through the mountains of New Mexico?

A.T.I. They're conserving their coal and oil, and that's why they're developing so much hydro and wind power. But I want to know what's going on in the rest of the world. Let's look at Africa. How about it, Hank?

H.M.P. Righto! Just a minute, now. Here we are!

A.T.I. I guess you didn't hear me. It's Africa I wanted.

H.M.P. This *is* Africa. You just don't recognize it!

A.T.G. Sure, it's Africa. Look at all those hydro plants along the Congo River! Now, that's *really* worth waiting for!

D.R.H. What's happened to the deserts? Most of them are under cultivation! That's what I call irrigation!

H.J.S. They must have changed the chemical content of the soils and added organic cultures, or they couldn't grow crops in the deserts, even with plenty of water. And they must be dealkalizing and desilting the water so that the soil doesn't get salty and clogged. If I didn't see it, I wouldn't believe it!

R.E. Nothing to it, Herman. They run the irrigation water through treatment plants — just a little problem in sanitary engineering.

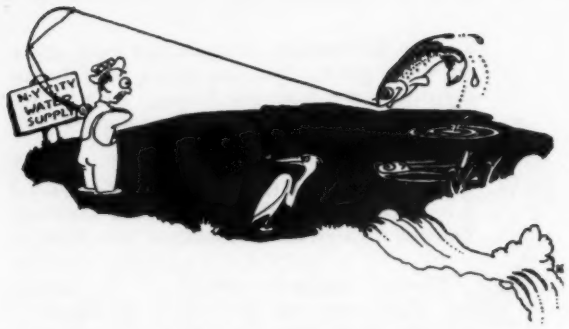
A.T.G. The hydrologists are working with the meteorologists, too! I always said they would come to it! Look! They're making artificial rain over the drainage basin of the Nile!

H.J.S. It's a good thing that they're doing all this; with its big population the world would be underfed if they didn't. They need to grow food under practically every condition of climate, and they're doing it.

A.T.I. Drainage is important, too! See how they've drained that jungle, and put it to crops!

A.T.G. There's a river that hasn't been developed yet. Looks like they're just getting around to it. What are those airplanes doing up there?

H.J.S. They're surveying the site! No more plane tables, boys. It's all photogrammetry now!



A.T.G. Yes, but what's that airplane doing 'way over there on the horizon? That one isn't even over the drainage basin.

H.J.S. It's prospecting for gravel for the dam. That's the way they do it now. You can spot it from the aerial photos – even subsurface gravel, if it isn't too deep.

J.W.D. They seem to be blasting down by the dam site. That's funny – there isn't any rock down there.

D.W.T. That's a seismic investigation of subsoil conditions. And just when I'm getting my new boring device perfected!

J.B.W. Down there where they're starting to build the first dam – what's that chap doing sitting by that radio?

H.J.S. That's not a radio. It's an automatic electronic surveyor. It's giving them lines and grades for the dam. See that fellow up on the spillway? He's the rodman – only he doesn't carry a rod any more. See how he's holding that electronic target?

There are more notes here, but time is short, so I'll try to summarize them. Africa had indeed become the breadbasket for Europe, and in this great conversion, American capital, initiative, and the skill of hydraulic engineers had played major roles. With growing populations it had become necessary to grow food under all conditions of climate, and water was, of course, the key to this situation. Our hydraulic engineers, benefiting greatly by advances in aeronautics, oceanography, and meteorology, had so increased their skills in both hydraulic design and hydrology that water, one of our most basic natural resources, was being conserved in the true sense; that is, it was being used wisely in serving the needs of mankind. And they were doing this in a manner such that topsoil – that thin upper crust of earth upon which the food supply of the world depends – was conserved and used, rather than swept into the sea by erosion and floods. More extensive development of water power and the rapid growth of wind power was also important in connection with the conservation of nonrenewable fuels. This long-range point of view had been an important factor in leading to water- and wind-power developments all over the world, many of which, by the narrower concepts of engineering economics so prevalent 25 years earlier, would not have been considered as economically justified.

I have separated sanitary engineering from hydraulic engineering in my Paynterscope notes, because while the former has much to do with water, it is more concerned with those biological and chemical processes by which it can be made to serve the needs of mankind more effectively. Under this heading, the following comments may be of interest:

R.E. What I want to know is: Are the sanitary engineers really on their toes so that they appreciate the importance of the basic sciences, or have the chemical engineers taken over some of the fields?

C.N.S. Stop worrying, Rolf. The sanitary boys are right on the ball! See how they're treating all those industrial wastes? That's a really important part of sanitary engineering, now.

R.E. You're right, Clair. Thank goodness for that! See how they're treating the discharge from that atomic-energy plant! And at that film manufacturing plant they're treating the water *before* they use it, to get rid of any trace of radioactive substances.

W.E.S. The hydraulic engineers can't take all the credit for conserving our natural resources. Don't those streams and lakes look fine? No more pollution!

M.P.H. That's wonderful for the health of the public.

C.N.S. And for recreation, too. I wouldn't mind getting out my rod right now, and trying for a trout in that stream. And swimming! The Charles River didn't used to be fit to swim in.

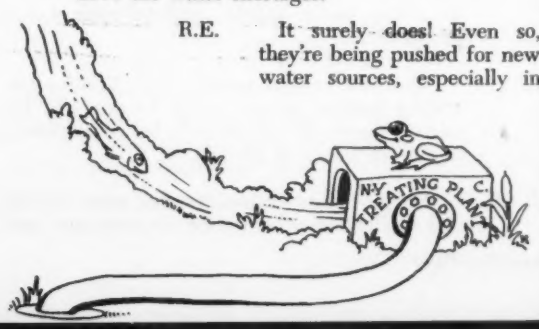
W.E.S. Those water-treatment plants on the Hudson don't look very big.

C.N.S. They don't have to be big. They're using new processes that are a lot quicker. They handle the water at such a high rate that the plants can be small.

R.E. That's important, because they don't cost as much. That's why they can afford so many of them. Look, practically every town is treating its water!

W.E.S. That goes for sewage plants, too. They're certainly using faster methods of treatment. Say, there's an interesting thing! Notice what they're doing with the sludge from the sewage plants and the refuse from the cities. They're not burning up the organic matter any more; it's all being used for fertilizer! And the effluent isn't being dumped into the ocean; it's either being used for irrigation or being pumped back into the ground to raise the ground water level! That ought to help relieve the water shortages!

R.E. It surely does! Even so, they're being pushed for new water sources, especially in



the big cities. Look at those new plants along the shore on Long Island! They're treating sea water chemically and using it to help out the water supply for New York City!

W.E.S. I wonder if they've done anything about corrosion? We used to lose a lot of our water through leakage.

C.N.S. They certainly have! The treatment plants almost all include one treatment to make the water noncorrosive, and everywhere else the pipes are lined with special plastics!

I think that these remarks will give you a good idea of the future of sanitary engineering, but I'd like to stress a few points. The major advances had been achieved as a result of basic research in biology and chemistry, and had led to new methods of treatment that were both rapid and economical. Speed of treatment was especially important since this led to much smaller treatment plants, which, being cheaper to build, had become economically available to almost every city and town for both water and sewage. This was equally important in the field of industrial wastes, since industrial plants were more willing to attack this problem voluntarily and it had become less necessary to resort to legislative pressure. In this connection, the reclamation of by-products from industrial wastes – often leading to financial returns that exceeded the cost of treating the wastes – was a noteworthy factor.

The sanitary engineer had without doubt become a key figure in the battle to conserve our natural resources, not only by helping to use our water more effectively and reclaiming for re-use the solids from both sewage and industrial wastes, but by cleaning up our lakes and streams, leading to larger crops from our wildlife, as well as greatly improved recreational facilities.

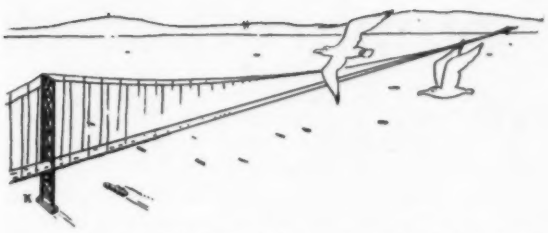
Let us return for the last time to my notes; this time for structural engineering, including foundation engineering. Of course, many of the structures we saw on the Paynterscrope had been built in connection with transportation engineering, hydraulic engineering, and sanitary engineering. Yet, for convenience, I have grouped the following remarks into a separate section.

E.M. That railroad bridge seems to be welded. I guess they aren't worried about the effects of impact loads and stress reversal on welding any more.

C.H.N. Yes. Practically all the metal structures are welded – even that aluminum arch!

E.M. Aluminum? It looks as though the price must be 'way down. Probably the wartime aluminum capacity has led to that. But notice the lighting on that elevated expressway. Continuous fluorescent lights along the handrails, isn't it? And aren't they using radiant heating in the floor slabs to melt the snow and ice?

M.J.H. Yes, they are. And notice that it's a concrete viaduct. Prestressed concrete, too. Look at the length of those spans! They've certainly cut the



dead weight out of the structure, and they must be using higher working stresses. Why, there's a concrete arch with a span of 1,500 feet! Who said that concrete couldn't be used for long-span bridges?

J.M.B. You call that a span? How about that suspension bridge? It must be at least two miles between the towers!

M.J.H. It is! But do you know how they've done it? The cables are spun of glass threads. They're stronger than steel and they are working stresses of a quarter million pounds to the square inch! They're using glass cables to prestress concrete, too!

E.M. Look at that continuous cantilevered Vierendeel truss with the inverted spandrel arch stiffening trusses! What an idea for the final exam in 1·41!

M.J.H. Those thin shell concrete domes are even better! The boys could never figure out one of those. I couldn't even do it myself! Those domes must be at least 1,000 feet in diameter, and they aren't over six inches thick at the crown. Talk about your eggshell construction! I'll bet they're prestressed!

C.H.N. And the thin rectangular dome roofs on those industrial buildings. They must have a clear working span of at least 500 feet!

E.M. Have you noticed that most of the industrial buildings are single-storied? That must be partly on account of decentralization and using lower cost land.

J.B.W. And that must account, too, for the fact that there aren't more skyscrapers. That 150-story building on Manhattan is a corker, but on the whole the other buildings aren't much higher than we build them today.

R.J.H. I noticed five heavy buildings in Boston that must have been designed to resist A-bombs, but I'm surprised that there aren't more of them.

J.M.B. Maybe they didn't have an atomic war after all, and didn't have to go on building them. You know those A-bomb buildings in Boston must be on piles to bedrock. The Boston blue clay would never hold them up!

(*Continued on page 254*)

Stepbrother to the Iron Horse

THE United States of the latter 1880's was both very much like the country we know today, and very different. It had many of the same houses, the same cities and towns, the same daily papers, the same politics, the same scandals. Although radio, movies, and television were only fantastic dreams, today's jokes were heard in the variety shows, and the dramatic companies, at the local opera house, used the same plots we now witness. Running water was available in cities and in the larger towns, and telephones and electric lights were coming into general use.

To outward appearances, at any rate, the biggest difference between the nation of 1952 and that of seven decades earlier was in local transportation. In the half century, from 1830 to 1880, the railroads had grown from a few small beginnings to a network reaching every worth-while town in the nation, and canals and stagecoaches had declined to insignificance. Nevertheless, local public transportation was pretty much limited to the larger cities, and was slow and fairly expensive. Private transportation, by horse and buggy, was a necessity for the farmer, but it was still a luxury for townspersons, even the more prosperous ones.

The horsecar had gotten its start in New York in 1832 as a downtown extension of the New York and Harlem Railroad. For nearly 20 years, this one line plodded along, and then suddenly, in the 1850's, a craze for horsecars swept the larger cities. Economic reasons were partly, if not largely, responsible for this trend, for, on a track, a horse could haul about twice the load that he could pull over rough cobblestones or rutted dirt roads. But the spirit of the times also contributed to this new mode of transportation, for the iron horse was revolutionizing the way of life throughout the entire country, and anything that ran on rails simply had to be good.

Although the horse was slow, of limited power, expensive, and short-lived, many people held it to be axiomatic that no mechanical contrivance could ever improve on him. Yet the inventors kept striving.

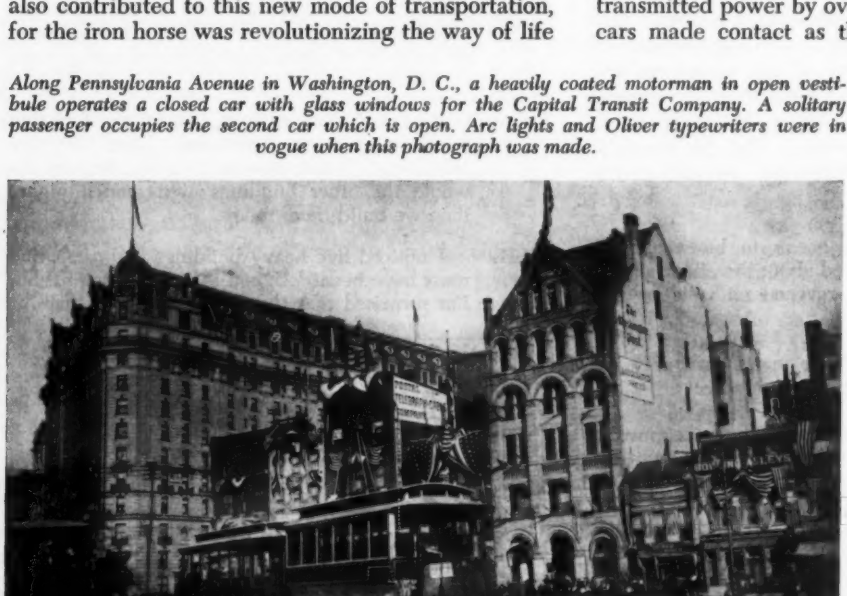
In meeting the transportation needs of the day, a few hardy pioneers turned to steam power, which was tried and proven. On street railways, they used miniature locomotives called "steam dummies," disguised like cars so as not to scare the horses. Although effective, the steam cars were smoky, noisy, and expensive. Out of San Francisco, daring Andrew S. Hallidie conquered the steep hills by using a stationary steam plant to move an endless cable in a slot between the car rails and equipping each car with the gripper which allowed it to take hold of the cable or to release it as desired. Cable cars were economical to operate, quiet, clean, and somewhat faster than horsecars, and these advantages outweighed the objection of high initial cost. Consequently, in the last quarter of the Nineteenth Century, lines were built and cars operated in New York, Chicago, Philadelphia, St. Louis, Oakland, Denver, Washington, Kansas City, Cleveland, Providence, Seattle, Baltimore, Brooklyn, Los Angeles, Hoboken, and Omaha.

From Horsecars to Electricity

Meanwhile, other inventors were experimenting with that invisible, imponderable, exciting form of power known as electricity. Some inventors employed the heavy, bulky storage batteries as the source of motive power without much success, while others transmitted power by overhead wires with which the cars made contact as they moved. There is much dispute as to whether Leo Daft, Charles J. Van Depoele, Frank J. Sprague, or Elihu Thomson produced the first successful electric car. It is conceded, however, that the 40 cars Sprague equipped with motors at Richmond, Va., in 1888 constituted the first large-scale electric railway operation.

At that time the country's largest street railway was Boston's West End system, which then owned 8,000 horses. In 1889, following his Richmond installation, Sprague came to Boston to install a street railway system run by electric power. The same year, the Thomson-Houston Electric Company,

Along Pennsylvania Avenue in Washington, D. C., a heavily coated motorman in open vestibule operates a closed car with glass windows for the Capital Transit Company. A solitary passenger occupies the second car which is open. Arc lights and Oliver typewriters were in vogue when this photograph was made.



During Their Heyday, between 1880 and 1915, Trolley Cars Supplied Interstate Transportation by Railway Systems of Interconnecting Networks

By HENRY B. BRAINERD

In New York's Battery Park district, a jaywalking pedestrian decides to watch out for traffic, after narrowly escaping being run down by a four-wheel horsecar of the Belt Line which operates between South Ferry and Central Park with a crew of two.

which had bought out Van Depoele and combined his inventions with Thomson's, installed their electric system on a West End line in Cambridge.

Significance of Street Railways

That marked the turning point for electric traction. In 1890, a survey by the Boston *Advertiser* showed, there were 60 cities with trolley lines either in operation or under construction. From then on, the growth of electric trolley systems continued to be rapid. Soon every city of any size had its trolley system, and suburban and rural lines were extended and interconnected until it was possible to travel long distances without resorting to "steam cars."

The network of urban and suburban lines, which sprang into being toward the end of the Nineteenth Century, ushered in a new phase of public transportation over moderate distances which had important social and economic significance. The importance of this development has not always been sufficiently appreciated, nor has it been properly understood; certainly, it has not been adequately chronicled. Nevertheless, this technological development opened up, for the first time, the possibility of suburban living even though the full impact of suburban life was not to be realized until decades later when the automobile became commonplace. With interurban lines operating between towns and extending into the country, the city dweller could be freed from the restricted confines of the metropolitan area. Now the poor man could ride many miles to the beach or to the picnic grounds for only a nickel, and he could arrive at his destination more quickly and comfortably than the rich man in his carriage.

The power plant of a typical early line consisted of one or two 500-volt, direct-current generators belt-driven by reciprocating engines. Each unit was usually rated at no more than 100 horsepower. Power from the generating station was transmitted either via feeders or directly by the trolley wire to cars each carrying one or two 15-horsepower motors. In the Sprague system, the motors were controlled by a drum switch at either end of the car, connecting to resistor grids underneath, while the Thomson-Houston system provided a circular rheostat some three feet in diameter, with a chain-and-sprocket connection to a hand crank at each end. However, the Thomson-Houston rheostat soon disappeared. Speeds of 10 to 15 miles per hour were typical.

Sometimes the cars were horsecar bodies mounted on electric motor trucks, but more often they were newly built for the job, being somewhat larger than the horsecars, but of the same design. The typical closed "box" car for cold weather had only four wheels, seats facing lengthwise, end platforms open to the air between the waist-high dash, and the overhanging roof, and a body that curved inward below seat level. The curved sides were a last vestige of the stagecoach, which had to be wide at seat level but narrow between the wheels. For summer, there were open cars with benches clear across the width of the car and a running board along the full length of each side, as shown above for the horsecar.

With different types of cars for summer and winter use, a trolley line had a double investment in cars. Perhaps the extreme in the large number of cars used for a small system was reached in the Newton Street Railway. This line ran three cars, and in rush hours, a horsecar would be coupled behind each motor car. A spare car was needed of course, so rolling stock of this line consisted of four box cars and four open motor cars, four box horsecars, and four open horsecars, and "one old horsecar used as a sand car." Hence, a total of 17 cars was employed to support operations which did not normally require more than three cars at a given time.

Track construction had made great strides since iron straps on wooden stringers sufficed for the first horsecars. On paved streets, the 1890 trolley ran on a six-or-seven-inch girder rail weighing around 80 pounds to the yard, with a groove or a step for the flange. For unpaved roads and open right of way, the track was usually a 40-to 50-pound T rail of the American Society of Civil Engineers standard section.

Although it had not been successful for traction, well-informed people believed that the storage battery would soon be improved sufficiently to warrant its satisfactory use in vehicles. About 1894, the promoters of the Newton and Boston Street Railway argued that their line should be allowed to use wooden poles to support their trolley wire instead of the more expensive iron poles, because by the time the wooden poles were worn out, practical storage batteries would be available, and then the trolley wires would be taken down. Hope for better primary batteries was not dead either. As late as 1897, a civil engineer, building Boston's South Station, remarked that the locomotive of the future would use "a lump of zinc the size of your fist" as a day's fuel supply.

Railroad Empires in Miniature

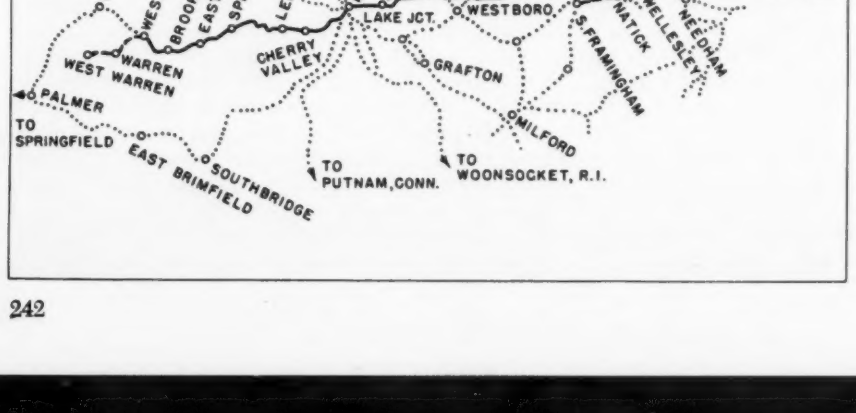
Trolley systems of the 1890's were railroad empires in miniature. They had the same cutthroat rivalries – political and financial – and much the same romance. Steam-railroad men had a good-natured contempt for trolleys, though when a suburban line competed with established steam service, this became bitter animosity. But trolley men referred to their occupation as "railroading" with every inch of pride that the word could carry.

By 1900, the trolley car was firmly established as an important means of passenger transportation. True many outlying lines were not yet paying, but the number of street railway passengers was doubling every 10 years, so it was thought to be merely a matter of time before accounts would be kept in black ink instead of red. In the cities the major problem then – as now – was how to handle the crowds. Most companies operated the larger cars with two four-wheel trucks by 1900, but even these were not big enough for all the passengers who wanted to ride. About this time, enclosed vestibules and air brakes were generally adopted, and the newer closed cars were built with squared-out sides and cross seats. Car speeds were usually 20 miles per hour and might reach 25 or 30 miles per hour. In Boston there had been a perpetual traffic jam of trolley cars, relieved only by the opening of America's first subway, under Tremont Street in 1897. With two or even four 40-horsepower motors per car commonplace by 1900, power demands were larger than a decade earlier, and generating capacity had been increased accordingly. Alternating-current power, transmitted at high voltage to converter substations, was being tried here and there. Capital and labor costs for converter stations were about as much as that required for steam stations, and the large capital cost of transmission lines offset the small saving which better fuel efficiency in the large central station afforded.

About the turn of the century, electric railway construction shifted from the city to the country, and the next 15 years saw the completion of an extensive network of long-haul, high-speed, interurban lines. The most extensive of these was the network extending from mid-New York State to St. Louis, Chicago, and Milwaukee, but other similar lines made connections between such points as Boston and Worcester, Philadelphia and Allentown, Los Angeles and San Bernardino, Ogden and Salt Lake City, and Atlanta and Stone Mountain. These lines made use of existing trolley tracks in the cities and often built their cross-country rights of way to the same standards as a secondary steam railroad. So far as the curves and clearances of city trackage would permit, the interurban cars likewise approached steam railroad standards of size, weight, comfort, and appearance. Steam railroad developments in the use of steel, first in underframes and then for entire cars, were promptly adopted for interurban and for new city cars. Motor sizes increased with car weight. Speed between towns was seldom less than 30 miles per hour, and top speeds up to 60 miles per hour, were not uncommon.

The improved efficiency of large generating plants led to the general use by interurban lines of alternating-current transmission. Power was usually generated at 25 cycles, and transmitted to substations where it was converted to 600-volt, direct current and fed to trolley lines. A few lines used 1,200 to 1,500 volts direct current with heavily insulated motors in series pairs, and a few others used 25-cycle traction motors. But the majority stuck to 600-volt direct current, for which standard equipment was readily available. Most of the high-voltage and alternating-current lines had their cars arranged to use 600-volt direct current within city limits.

Map of the route between Needham and West Brookfield, Mass., which could be traveled entirely by trolley rides in 1914. Automobile highways traverse essentially the same route.
M.I.T. Illustration Service



Trip by Trolley

At the height of trolley railway systems, it was possible to make fairly extensive trips on interconnecting street railway systems. The Bay State Street Railway was the giant among trolley systems with a network of more than 900 miles of track between its farthest southern point at Newport, R.I., and its farthest northern point at Nashua, N.H. Few persons utilized the full mileage of such systems in a single trip, but shorter trips were exceedingly common and provided week-end diversions.

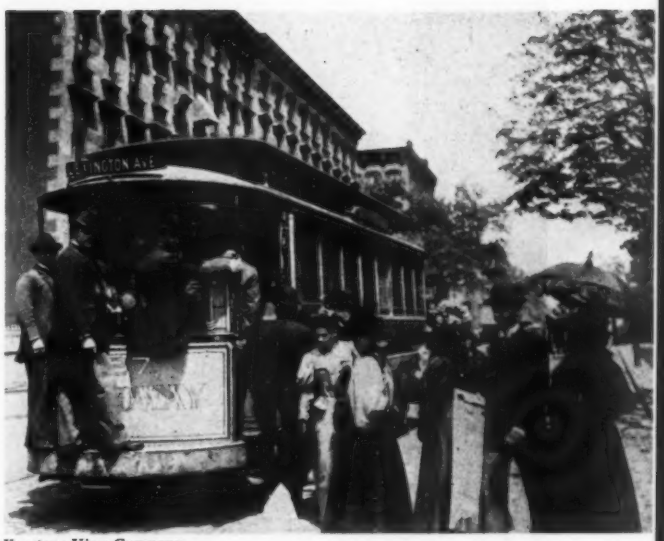
To visualize travel by trolley as it was at its height, let us turn back the calendar to 1914 and make an imaginary trip between two modest Massachusetts towns, Needham and West Brookfield. For purposes of orientation, it may be well to recall that Needham is just beyond the outskirts of Boston, while West Brookfield is 22 miles west of Worcester, so our trip will cover a distance of 57 miles, along the route marked by the heavy line on the accompanying map.

In Needham Square we board the car of the Middlesex and Boston Street Railway (a merger of the suburban lines west of Boston) for Wellesley. The bright yellow car is a tiny, old four-wheeler, and is far from full. Two things have contributed to the lightness of travel on this line; people tend to travel toward and away from Boston rather than between towns at about the same distance, and new houses, which would support heavy traffic on the line, have not been built to the extent expected. In time the conductor comes through the car, collects the $0.06 fare, and issues a punched transfer enabling us to continue our journey on this line to Wellesley Hills. The four-mile trip from Needham Square to Wellesley takes slightly more than 15 minutes. About half of the way, the track runs on the right side of the street, then it crosses to the left side for the remainder of the distance. This is typical of country trolleys.

At Wellesley, we have only a few minutes' wait for the car from South Framingham to Newton. It is the same bright yellow, but a much bigger car than the one in which we just rode. It was built in 1902 for the Boston Suburban Electric Company when they bought up the local lines which they merged to form the Middlesex and Boston in 1907-1908. The conductor comes to our seat to collect our transfer for, in the earlier days of streetcar transportation, it was possible to walk through a car; one might even get a seat. By 1914 many city systems had adopted a pay-as-you-enter fare collection, but this method had not spread to the Middlesex and Boston Street Railway. After five minutes, and a mile and a half of roadside single track, we make a sharp turn across the street and enter the Wellesley Hills turnout. This is the longest distance between turnouts on the whole line, and with a car every 15 to 20 minutes in each direction, it is a frequent source of delay.

It is in Wellesley Hills that we change to the Boston and Worcester Street Railway, commonly known as "the Trolley Air Line." This double track interurban line follows the direct but hilly route of the old stagecoach turnpike. The dark, olive-green cars run frequently. We board the first car, a Worcester local. The conductor comes to our seat, collects our through fare to Worcester, which is $0.47, and punches a check to identify how far we have paid. This will also serve as our transfer to a Worcester Limited.

In traveling through the New England countryside, we note a picnic grove, which is a favorite destination for Sunday car riders, and a few houses built to take advantage of this good transportation which has been available since 1903. At Natick Junction, the car behind us will turn off, then at Sunnyside we stop for passengers as we cross the Natick and Cochituate branch of the Middlesex and Boston Street Railway, originally a horsecar line built in 1887.



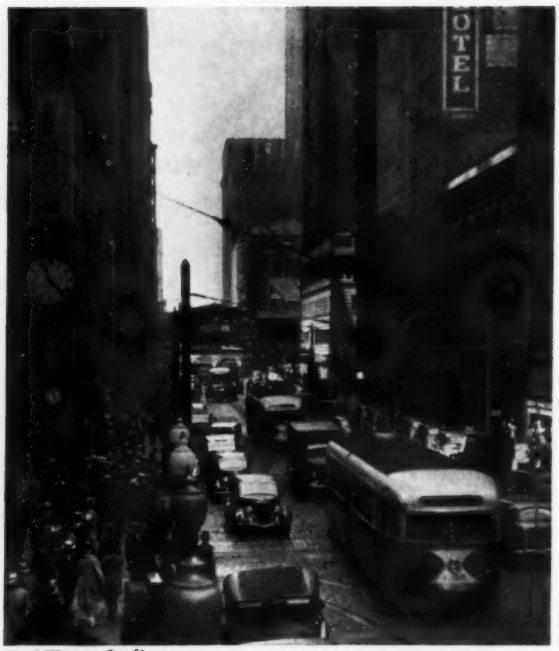
Keystone View Company

Then, as now, slogan of operators of New York's street transportation system evidently was "always room for one more." Now, however, in contrast to this view of an earlier day, it is hardly feasible to ride on the outside of the car.

After two or three miles of open country with hardly a house to be seen, we stop at Framingham Junction, where the Framingham-Saxonville Branch crosses the main line. The two-story headquarters of the Boston and Worcester Street Railway, a few houses, and the State Militia Muster Grounds are passed. At Framingham Center we pull into a side track in front of the big carbarn, alight, and walk over to the main track, where we wait only a few minutes for the Worcester Limited. This car left Park Square, Boston, an hour ago. For the first six miles it was operated by a crew of the Boston Elevated Company, but operation for the Boston and Worcester Railway Company took over at Chestnut Hill and brought the Worcester Limited 14 miles without a stop in 25 minutes. We pass through the village of Framingham Center, which was the original settlement in Framingham. When the railroad was built through South Framingham, the Center declined in importance. Now the trolley is bringing back a moderate amount of business.

On our left is the Union Avenue Branch connecting South Framingham to the Center. This and the Saxonville line were formerly the Framingham Union Street Railway, a horsecar system built in 1886 and not electrified until 1897, when James Shaw bought control as a preliminary to building the Boston and Worcester line.

The schedule between Chestnut Hill and Worcester on the 31 miles of track of Boston and Worcester lines is 62 minutes, with only three stops. Soon after leaving Framingham Center, we pass the Sudbury Reservoir and stop at White's Corner. Most of the way from White's Corner to Worcester is much like that of a steam railroad except for steeper grades. A passing eastbound freight car is a reminder that the Boston and Worcester Railway does not handle steam railroad freight cars like many of the interurban lines of the Middle West, but it does handle



Fred Wagner Studios

Long after the streetcar reached its heyday, fast, quiet streetcars were introduced on the Madison Street line in Chicago, but the automobile had replaced streetcars for suburban travel.

through shipments with connecting trolley lines as far as New Bedford and Springfield. Two important items of freight are beer and fresh fish.

The next stop is at Lake Junction, where the crew of Worcester Consolidated Street Railway takes over the car for the last three miles. The conductor exchanges our identification check for a free transfer, good anywhere in the Worcester local-fare zone. Soon we pass White City, the amusement park built by the Worcester Consolidated, with its roller coaster and many other attractions. Then on into Worcester.

As we approach the center of the city, other tracks come into ours, and we find ourselves in a veritable procession of trolleys. Most of the lines we see are double track. The Worcester Consolidated Street Railway is the third largest trolley system in Massachusetts with well over 300 miles of track. It operates through cars to Fitchburg, Springfield, Putnam, Conn., Woonsocket, R.I., and many nearer points, as well as a network of city lines in Worcester. This system, along with the Springfield Street Railway, the Berkshire Street Railway, the Rhode Island Company, and the Connecticut Company, is controlled by the New York, New Haven and Hartford Railroad. Cars of these companies are of the same color scheme – light yellow body, white trim, and red lettering.

We pass the railroad station where the long-haul trolleys of the Worcester Consolidated have their terminal, then come to the end of our run at Salem Square. A quick lunch can be obtained at the lunch counter in the waiting room. A short walk through City Hall Park and across Main Street brings us to the southbound stop on the final leg of our journey through Spencer, Brookfield, and West Brookfield. A dozen cars go by before ours comes along, marked "Spencer." The transfer we received at Lake Junction will permit us to travel to the city limits of Worcester without additional charge. At the outskirts of Worcester we notice a single track going down a side street to a building like a small carbarn. This is the factory of the American Car Sprinkler Company which builds trolley cars for sprinkling or flushing streets and leases them to railways over a large part of New England.

At the city limits, where the local cars marked "Leicester Line" turn back, we go from double track in the center of the street to single track at the roadside. Soon we pass the village of Cherry Valley, then the hilltop town of Leicester, and on to the next town, Spencer. Our progress is slowed by long climbs, cautions descents, and waits at turnouts. It takes us an hour to reach Spencer, and the fare is $0.15 after leaving the local zone covered by our transfer. In Spencer our car stops in the middle of the street at the end of the line.

The waiting car of the Worcester and Warren Street Railway takes us on the final stage of our trip. The Worcester and Warren Street Railway is a small independent line, running from Spencer through the Brookfields to West Warren. After another hour of hill climbing, with several turnout waits, and the payment of three additional $0.06 fares, we arrive at our destination, West Brookfield. The 57-mile trip from Needham to West Brookfield has taken four and a half hours and has cost $0.86.

It is possible to go on to Springfield by taking the Ware and Brookfield Street Railway to Ware, and then the Springfield Street Railway through Palmer. But most of the through riders go by the route farther south where the Worcester Consolidated and the Springfield Street Railway run through cars via Southbridge and East Brimfield. It takes three and a half hours to cover the 60 miles; this is said to be the longest regular trolley car run in New England. It was also possible to go from Boston via Worcester, Springfield, Hartford, Waterbury, and on to Bridgeport, and then return by any of the several different routes such as that of New Haven, New London, Westerly, and Providence. Special cars have made much longer runs, however, such as from Boston to New York for example.

The vast network of urban and interurban electric street railway systems (which were in extensive operation when World War I broke out in Europe) provided passenger transportation service which very well supplemented that offered by the steam railroads. For a decade or so the electric railways filled a growing need for personal transportation which was improved upon only when the private automobile became commonplace, and so long as they filled a social and economic need, they enjoyed their heyday – a precarious heyday for smaller rural lines.

Decline Sets In

Urban and suburban electric railway systems reached the peak of utility between 1900 and 1915. The beginning of World War I marked the end of large-scale trolley construction. Costs were rising while income from fares remained stationary.

(*Continued on page 270*)

The Renaissance in Metal Cutting

The Trade-School Approach to Machine-Tool Operations Is Giving Way to Scientific Analysis as Instrumentation and Analytical Methods Provide Fundamental Understanding of Operations

By MILTON C. SHAW

All basic fields of industrial endeavor have taken similar paths in the course of their development. The earliest work has generally been carried out on a purely empirical basis, and in many instances such activities have been highly developed by following the case method. While this method presents a clear picture of each specific job, a great many cases must be considered before sufficient examples have been presented to enable all common situations to be covered. This approach has been extensively used in metal cutting as well as in other fields, such as machine design, hydraulics, metallurgy, and even such nonengineering activities as law and medicine. The weakness of the method lies in its failure to provide a direct means for solving problems which lie beyond the range of current experience. Each new case that is established must be arrived at by a costly procedure of trial and error.

Not too many years ago, steam turbines and power machinery were designed largely in accordance with the judgment of the designer, rather than by following the more rational approach, involving stress analysis, that is in wide use today. Similarly, the design of hydraulic conduits and machinery that once was done by rule-of-thumb procedures is now being accomplished largely with the aid of the principles of fluid mechanics. In the field of metallurgy, steelmaking is being carried out by considering it a special problem in physical chemistry, instead of employing the ago-old recipe technique. Metal-cutting tools and procedures are still largely established by the old case method. This activity has resisted the impact of modern technology and the scientific method, mainly due to the complexity of the operations, but also partly due to the attitude held toward metal cutting in our engineering schools.

The Educational Position

Traditionally, metal cutting has been part of the training of mechanical engineers in this country. However, in the past, a trade-school approach has generally been adopted, the emphasis being placed entirely upon nomenclature, the mastery of machine manipulation, and the learning of a large number of disconnected empirical rules. In some instances the major objective has actually been the production of trinkets, thus appealing to the hobby instincts of the student rather than offering him a means of exercising his facility to apply fundamental concepts and developing his analytical ability.

In the past, metal cutting has been an almost exclusively undergraduate activity. The extensive graduate research program that is so necessary in supplying the spark needed for effective graduate teaching has been largely missing. There are relatively few people with fundamental learnings who have found their way into production activities due to the fact that students, who are analytically inclined and take naturally to the rational approach to problems, have not been attracted to study metal-cutting operations. This also explains why the production industries, in the main, have not instituted a great amount of fundamental research in the past.

About three years ago it was recognized that a renaissance in metal-cutting activities is just as inevitable as it was in the fields of power-machinery design, hydraulics, and metallurgy. Under the guid-

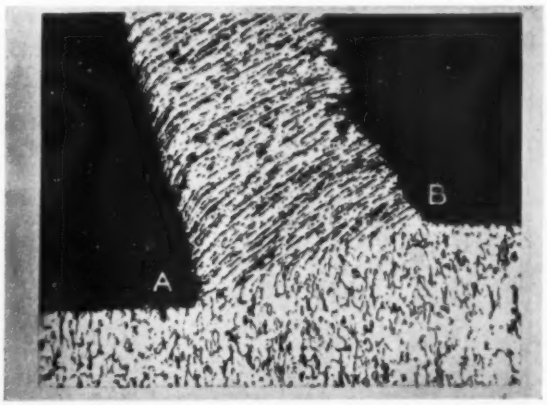


Fig. 1. In the process of metal cutting, tool tip, A, produces chips above the line AB with no deformation of the metal below this line.

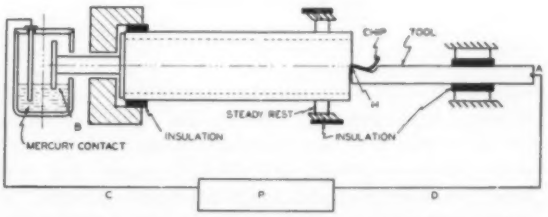


Fig. 2. If the work to be cut and the cutting tool are insulated from the machine, the dissimilar metals at the cutting point, H, may be used as a thermocouple to determine tool chip temperatures.

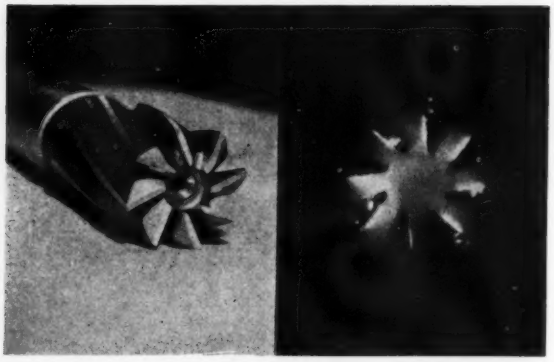


Fig. 3. After cutting a radioactive piece of metal the cutter, (left) was placed on photographic paper to produce the image, (right) proving that metal from the workpiece had been transferred to the mill end.

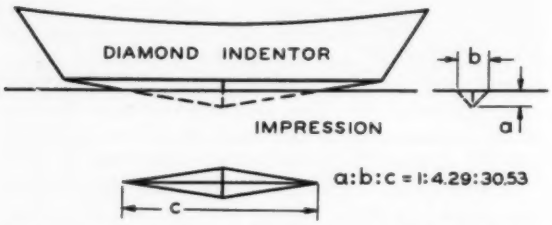


Fig. 4. Diagram of diamond indenting tool used to make impression in cutting tool to determine wear during use.

Fig. 5. Photographic reproduction of cutting edge of a ground surface, showing grooves and jagged edge left as a result of the grinding operation.

ance of Professor C. Richard Soderberg, '20, Head of the Department of Mechanical Engineering at the Institute, the necessary administrative changes were made to insure that M.I.T. would not only meet the needs brought about by these changes but would actually be in the vanguard of the movement. Developments which have recently taken place to strengthen the Institute's position in the field of metal cutting may be summarized as follows:

1. *Teaching Program:* The classical introductory matter presented to undergraduate students is being streamlined and integrated with more fundamental information as it becomes available from research laboratories. Here, the objective is to describe precisely what happens in a cutting process in terms of fundamental concepts, and where possible, to make the treatment quantitative. Cutting dynamometers and temperature-measuring techniques are now regularly employed in the undergraduate instruction in Machine Tool Laboratory. A subject dealing with advanced analysis of cutting techniques is now being regularly presented at the graduate level.
2. *New Division:* A Machine Tool and Metal Cutting Division in the Department of Mechanical Engineering has been organized to administer the research and teaching programs in this area. By this action metal cutting is now recognized as a legitimate professional engineering subject and thus takes its place among the other older academic divisions of the Department of Mechanical Engineering, which include: thermodynamics, applied mechanics, machine design, and materials engineering.
3. *New Facilities:* The Machine Tool Laboratory has been recently modernized and many new tools have been added to those already available. A variety of special test apparatus has been assembled and is now in use. Some of these facilities will be mentioned later.
4. *New Building:* Through the generosity of Alfred P. Sloan, Jr., '95, a new Metals Processing Laboratory is nearing completion. In the near future this modern million-dollar structure will house the research and teaching activities of M.I.T. in the machine-tool field.

Research Techniques

A variety of techniques have proved to be valuable in the study of the metal-cutting process. Probably the simplest and most easily applied are those of a visual nature. Direct observation of the cutting process through the microscope, or the study of motion pictures that have been taken through the microscope during cutting, clearly reveals that metal cutting is basically a shear process. When a metal is cut it is plastically deformed very suddenly in shear. A photomicrograph of a partially formed chip is shown in Fig. 1. This picture was prepared by suddenly stopping a tool in the process of making a cut, cutting away the material in the vicinity of the tool point, and polishing and etching the surface following the usual metallographic technique. A sharp line extending from *A* to *B* is evident in Fig. 1 which shows that all plastic deformation occurs suddenly in cutting, there being no deformation below *AB* and no change in the amount of plastic deformation above *AB*. Cutting is thus seen to be a process that is carried out at very high strain rate. The thickness of the chip, relative to the depth of cut, is a measure of the amount of shear strain to which the metal has been subjected in cutting. As in all deformation processes, this unit strain is a very important quantity. It may be determined by visually observing the ratio of the chip thickness to the depth of cut.

A complete knowledge of the system of forces that obtain at a tool point is also of considerable value. Instruments that enable the resultant force to be resolved into a convenient set of components are called dynamometers. The availability of the wire resistance strain gauge in recent years has made it possible to measure force components precisely without mutual interference between the components. The force and torque components that are read with such instruments during cutting make it possible to determine such quantities as the cutting power, the mean shear stress on the shear plane, and the coefficient of friction between chip and tool face. The cutting dynamometer is one of the most useful tools available for studying cutting operations.

The mean temperature along the face of a cutting tool is of primary interest in basic tool studies. Such a temperature cannot be measured by embedding thermocouples in the workpiece a short distance below the surface, or by following any of the other usual laboratory techniques. Chip-tool temperatures can be measured easily however by making the interface between the chip and the tool the hot junction of a thermoelectric circuit. The dissimilar metals, of tool and workpiece, in contact cause a thermoelectric electromotive force to be generated when the chip-tool interface undergoes an increase in temperature. The method of applying this technique to a metal-cutting operation is shown diagrammatically in Fig. 2. This method was first used by the late Henry Shore, '24, in 1924 and is described in his master's thesis of that year, at M.I.T.

The improvement of tool life is one of the major concerns of the production engineer, and one of the chief reasons for tool replacement is wear. As in other abstract wear studies, the use of the radioactive tracer technique, in which one member of a rubbing pair of metals is made radioactive, has proved of value in tool wear studies. The autoradiograph shown in Fig. 3 of the end mill, also shown in Fig. 3, demonstrates that some metal transfer occurs even under the most advantageous cutting conditions. Here cutting conditions were arranged to be optimum, and the autoradiograph, produced by allowing the used and cleaned cutter to rest on a photographic film in darkness for one week, indicates the presence of significant amounts of metal transferred from the radioactive workpiece. From tests of this sort it may be concluded that even under the most favorable cutting conditions there will be some transfer and build-up of metal from the workpiece onto the cutting tool.

In the shop the wear of a cutting tool is usually followed by noting the rate at which a wear land develops on the clearance face of the tool, but this procedure is slow and inaccurate. Recent experiments in the Metal Cutting Research Laboratory at M.I.T. have shown it possible to speed up tool life studies by use of a diamond impression. The tool to be studied is first provided with a small flat about 0.010 inch wide on the clearance face of the tool, to simulate the conventional wear land. A small amount of cutting will cause this surface to wear in and assume the shape of a naturally produced wear land. A diamond indentor, shaped as shown in Fig. 4, is then pressed into the center of the 0.010-inch wear land without removing the tool. As the tool is worn in use and the wear land develops, the amount of wear may be precisely determined by observing the change of distance c in Fig. 4.

It will be noted that this method provides a 30.5 to one magnification of the amount of wear. Inasmuch as the wear rate is found to be linear with time, it is possible to estimate the life of a tool by cutting a relatively small amount of material.

(Continued on page 264)

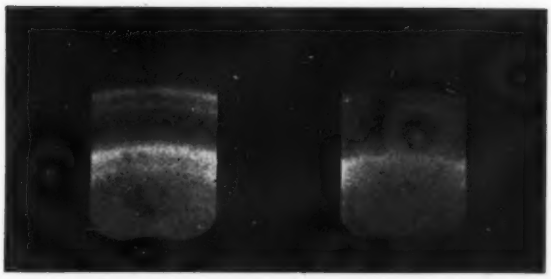


Fig. 6 (Above) *Radiography is an effective tool in studies of metal cutting. Refraction pattern of sharply defined arcs* (left) *are obtained from well-annealed metal. When metal is cold worked, as by grinding, for example, the refraction patterns are diffuse* (right).

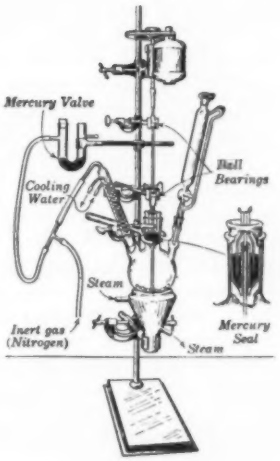


Fig. 7. (Right) *Glass apparatus previously used for producing Grignard reagents in a slow and hazardous small-scale operation has now been replaced by a safe, continuous process employing metal cutting.*

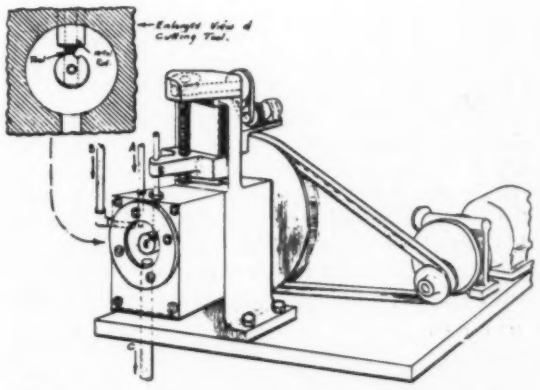


Fig. 8. Apparatus for cutting magnesium in presence of liquid reactants replaces the slower and more dangerous Grignard process illustrated in Fig. 7.

THE INSTITUTE GAZETTE

PREPARED IN COLLABORATION WITH THE TECHNOLOGY NEWS SERVICE

Hazen to Succeed Bunker

HAROLD L. HAZEN, '24, Head of the Department of Electrical Engineering at the Institute since 1938, will become dean of the Graduate School next July. Dr. Hazen will succeed John W. M. Bunker who has been dean of the Graduate School since 1940. Dr. Bunker, who joined the Institute's staff in 1921 as an assistant professor of physiology and biochemistry in the Department of Biology, will retire at the end of the academic year.

Professor Hazen was born in Philo, Ill., in 1901, and received from M.I.T. the degrees of bachelor of science in 1924, master of science in 1929, and doctor of science in 1931. He worked in the Schenectady and Pittsfield laboratories of the General Electric Company before joining the Institute's staff in 1925 as a research assistant, and subsequently obtained experience with both the American Telephone and Telegraph Company and the Raytheon Manufacturing Company. He was named instructor in Electrical Engineering in 1926 and assistant professor in 1931. From 1934 to 1935 he was a member of the faculty of Ohio State University in the first of M.I.T.'s exchange professorships. Dr. Hazen became an associate professor at the Institute in 1936, was placed in charge of graduate study and research in Electrical Engineering from 1937 to 1938, and was promoted to full professor and head of the Department of Electrical Engineering in 1938.

At M.I.T., Professor Hazen has co-operated in the design and construction of several important electrical devices, including the network analyzer, upon which power systems are reproduced in miniature for the solution of electrical engineering problems. He was also associated with the development of the differential analyzer which was designed by Vannevar Bush, '16, formerly Vice-president of the Institute.

During July and August of 1951, Dr. Hazen headed the Commission on Engineering Education which visited Japan for consultation with the Japanese Ministry of Education, as well as educators and administrators of engineering colleges there. This commission, consisting of 15 of the nation's leading engineering educators from 12 engineering schools in the United States, was organized by the American Society for Engineering Education and the Unitarian Service Committee, Inc., at the request of the Supreme Commander for the Allied Powers.

Professor Hazen, who was second lieutenant in the Air Service Reserve from 1924 to 1929, and lieutenant commander in the United States Naval Reserve from 1936 to 1949, served during World War II as chief of Division 7 of the National Defense Research Committee. In this post he worked from 1942 to 1946 in the field of ordnance fire control. Dr. Hazen was awarded the Presidential Certificate of Merit, the second highest civilian award, in October, 1948.

The Franklin Institute awarded him the Levy Gold Medal in 1935 for outstanding technical papers which appeared in that institute's journal, on the theory and design of servomechanisms. Dr. Hazen has contributed notably to the technical literature in electrical engineering, especially in the field of instrumental calculation, automatic control devices and engineering education. Since 1948 he has been a member of the Advisory Council of the Department of Electrical Engineering at Princeton University, and in 1949 was a member of the panel on Science and Engineering of the Service Academy Board. He is chairman of the Region II Committee for Undergraduate Engineering Curricula of the Engineers' Council for Professional Development, a group which provides the officially recognized list of accredited engineering curricula in the United States, based on inspections by the regional committees.

M.I.T. Photo

M.I.T. Photo

Two important changes in administrative posts have been announced at M.I.T. recently.

Professor Harold L. Hazen, '24, (left) *who has been head of the Department of Electrical Engineering since 1938, will become dean of the Graduate School on July 1, succeeding John W. M. Bunker who will retire. Professor Hazen is widely known as a scientist, an educator, and as administrator of the Institute's largest Department.*

Professor Ernest H. Huntress, '20, (right) *has been appointed director of the Institute's Summer Session, succeeding Frederick G. Fassett, Jr. Professor Huntress has been a member of the staff of the Department of Chemistry for the past 31 years and has been active on various educational committees at Technology.*

Huntress Heads Summer Session

ERNEST H. HUNTRESS, '20, who joined the staff of the Department of Chemistry at the Institute in 1920, has been appointed director of the M.I.T. Summer Session, President Killian announced in January. In his new post, Dr. Huntress will succeed Frederick G. Fassett, Jr. who was recently appointed associate dean of students. Dr. Huntress will continue the development of the Institute's summer program, extending its scope and its service to industry and education. Since 1950 he has devoted a portion of his time to the Office of the Dean of the Graduate School, serving as deputy dean, and he will continue to assist the dean of the Graduate School at M.I.T.

Born in Laconia, N. H., Dr. Huntress received his early education in the schools of Lynn, Mass., and was graduated from Classical High School in 1916. After entering M.I.T. with the first class to occupy the present buildings in Cambridge, his bachelor of science degree of 1920 was followed by that of doctor of philosophy in 1927. Joining the staff of the Department of Chemistry as an assistant 31 years ago, Dr. Huntress rose to the rank of professor of organic chemistry in 1941. He has been concerned with teaching and research at both undergraduate and graduate levels, serving seven years as head of the undergraduate division of organic chemistry and 11 years as chairman of the Graduate Committee of the Department of Chemistry. During the latter period, he was chemistry representative on the M.I.T. Committee on Graduate School Policy.

Dr. Huntress is a member of the M.I.T. Solar Energy Conversion Committee, a member of the board of the Technology Press, and this year completes his third term as chairman of the M.I.T. Faculty Committee on the Library. He is librarian and member of both the Council and Publication Boards of the American Academy of Arts and Sciences, to which he was elected in 1936. A member of the American Chemical Society since 1921, he is a former chairman of its northeastern section and was, for eight years, a member of its Richards Medal Committee. Dr. Huntress is an associate editor of the American Chemical Society's Chemical Monograph Series, a member of its Committee on Foreign Compendia and Committee on Nomenclature. In 1948 he was a member of the Scientific Information Conference held at London by the Royal Society, and served also as official representative of the American Documentation Institute to the International Federation of Documentation at The Hague.

His technical publications include nearly 100 scientific papers and patents, and he has contributed to *Proceedings of the American Academy of Arts and Sciences.* During World War II he served as technical adviser to the Chemical Warfare Service Development Laboratory at M.I.T. He is also the author of five books and has for some time been engaged in extensive biographical studies of distinguished men of science. Among his books are *Organic Chlorine Compounds* and *Problems in Organic Chemistry.* He is also coauthor, with the late Samuel P. Mulliken, '87, of *Identification of Pure Organic Compounds.*

Running for Office

ELEPHANTS and donkeys will play a part in elections this year as well as beavers. In ballots to be mailed toward the end of March, adherents of the Beaver party will elect new officers of the Alumni Association of M.I.T. into whose hands the administration of the Association will pass for one year beginning July 1, 1952. Alumni will also elect three of their number – each for a five-year term – to serve as members of the M.I.T. Corporation.

Edwin D. Ryer, '20, VI, Vice-president and Director of the Barbour Stockwell Company in Cambridge, has been nominated for the presidency of the Alumni Association, to succeed Alfred T. Glassett, '20, I.

The National Nominating Committee – composed of John L. Porter, '00, Donald B. Webster, '16, Winfield I. McNeill, '17, Walter R. C. Russert, '18, Harold E. Koch, '22, Harold C. Pearson, '23, Holland H. Houston, '24, George P. Edmonds, '26, George E. Colby, '32, and H. B. Richmond, '14, chairman – has

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HIGH OFFICE

Fabian Bachrach

. . . in the Alumni Association of M.I.T. will go to Edwin D. Ryer, '20, VI, unopposed candidate for president of the Association for the year beginning July 1, 1952. Mr. Ryer is vice-president and director of the Barbour Stockwell Company, manufacturers of machinery in Cambridge. Mr. Ryer has represented his Class on the Alumni Council, has been chairman of the Advisory Council on Tech Show, was class agent and member of the Alumni Fund Board, and is a former member of the Executive Committee of the Alumni Association. He is a director of the Jordan Hospital in Plymouth, and a member of the Duxbury Yacht Club.

Fabian Bachrach

Blackstone Studios

Curtis Studios

NOMINATED FOR ALUMNI TERM MEMBERSHIP ON THE M.I.T. CORPORATION

for five years beginning July 1, 1952, are: Everett S. Coldwell, '15, VI, President, Chairman of the Board and Director of Ford, Bacon and Davis, Inc. of New York; Alfred T. Glassett, '20, I, President of W. J. Barney Corporation of New York; and William L. Stewart, Jr., '23, XV, Executive Vice-president of the Union Oil Company of California.

nominated Dwight C. Arnold, '27, XV, as vice-president of the Association to serve for two years. Mr. Arnold is president and treasurer of Arnold-Copeland Company, Inc. of Boston. Theodore T. Miller, '22, XV – Vice-president of Dewey and Almy Chemical Corporation of Cambridge – and Stanley C. Dunning, '17, XV – manufacturers' representative in Cambridge – have been named for posts on the Executive Committee for two-year terms.

Named for alumni term membership on the M.I.T. Corporation, to serve five-year terms each, are: Everett S. Coldwell, '15, VI, President, Chairman of the Board, and Director of Ford, Bacon and Davis, Inc., a New York engineering firm; Alfred T. Glassett, '20, I, President of the W. J. Barney Corporation, in New York, and President of the Alumni Association for the year 1951–1952; and William L. Stewart, Jr.; '23, XV, Executive Vice-president of the Union Oil Company of California, and formerly chairman of Southern California M.I.T. Development Committee.

New representatives on the National Nominating Committee (one to be elected from each district) are: *District 1* – Boston – Raymond H. Blanchard, '17, X; *District 2* – Worcester – Ernest P. Whitehead, '20, I; Lawrence, Mass. – Dean K. Webster, Jr., '19, X; New Bedford – A. Russell Pierce, Jr., '31, XV; *District 4* – Rochester – Leon L. McGrady, '17, XV; Schenectady – Florence Fogler Buckland, '20, XIV; Syracuse – D. Earle MacLeod, '38, IX-B; Buffalo – Whitworth Ferguson, '22, VI; *District 5* – Newark – Walter L. Wise, Jr., '34, XV; New York City – Saxton W. Fletcher, '18, II.

This year the classes whose numerals end in the figures three and eight elect their class representatives for five-year terms, and nominations have been made by officers of their respective classes, beginning with the Class of 1893 and ending with the Class of 1948.

C. Adrian Sawyer, Jr.: 1881–1952

C. Adrian Sawyer, Jr., '02, President of the Alumni Association for the year 1949–1950, died at his home in Waban, Mass., on January 29 at the age of 70. He was active in civic and engineering construction affairs in Metropolitan Boston.

While attending Technology, Mr. Sawyer took an active part in student affairs. He was treasurer of the Technology Athletic Club and member of the Tennis Association. He served on the staff of *The Tech* and was editor in chief of *Technique* for 1902.

After graduation, Mr. Sawyer was an assistant in the Institute's Department of Mining Engineering for a year, and from 1903 to 1907 was employed by the Andrew D. Fuller Company. From 1908 to 1918 he was with the George A. Fuller Company and from 1918 to 1924 with the Howes Brothers Company. In 1924 he founded the Sawyer Construction Company of which he was president until his death. In his professional capacity, Mr. Sawyer has been responsible for the construction of many large medical and educational units, including the Sloan Automotive Laboratory and Building 24 at the Institute.

Mr. Sawyer has served as chairman of the Newton Board of Appeal, as president of the New England Peabody Home for Crippled Children, as director of the Suffolk First Federal and Loan Association, and as president of the Brae Burn Country Club. He was trustee of the Hahnemann and New England Deaconess Hospitals, and commodore of the Boston Yacht Club.

As a loyal Technology Alumnus, Mr. Sawyer was a member of the Alumni Advisory Council on Athletics in 1918-1919; a member of the Alumni Council from 1932 to 1944; a member of the Executive Committee of the Alumni Association from 1932 to 1934; and president of the Alumni Association for 1949-1950.

M.I.T. Expands Telephone Service

A NEW manual switchboard, the first of its kind in New England, was formally opened at the Institute on January 26, with a coast-to-coast telephone call from Joe E. Harrell, President of the New England Telephone and Telegraph Company, to James R. Killian, Jr., '26, President of Technology. Dr. Killian was in Los Angeles attending a conference of the M.I.T. Club of Southern California, where 200 Alumni attended a symposium on "Advances in Science."

The new switchboard with its additional dial lines – inaugurated before more than 250 representatives of the Bell system and M.I.T. in Huntington Hall – is one of the largest of its kind in New England.

In the long-distance telephone conversation, both sides of which were audible to guests in Huntington Hall, Mr. Harrell recalled that telephone progress "can be traced back to the technical skill demonstrated in the research that has been carried on by so many young Americans from schools like M.I.T." In reply, President Killian observed that this year also marks the 40th anniversary of the presentation to M.I.T. by the American Telephone and Telegraph Company, of the Deering Collection of about 30,000 volumes on electrical engineering. Long known as the Vail Library in honor of Theodore N. Vail, first president of American Telephone and Telegraph Company, this collection has now grown to 50,000 volumes. The Vail Library, President Killian stated, has had a profound effect on education in electrical engineering and is one of the outstanding libraries in electrical engineering in the world.

President Killian also recalled that there are about 375 Technology Alumni engaged in the Bell System, many of whom have held outstanding positions with Bell and its operating companies. This statement was well borne out by those who attended the inaugural ceremonies. Present from the New England Telephone and Telegraph Company were: Joe E. Harrell, President; Erskine N. White, Thomas M. Hennessey, Vice-presidents; James W. Thompson, Chief Engineer; James G. Moir, '20, Plant Extension Engineer; Winthrop F. Potter, '22, Transmission and Protection Engineer; Harris B. McIntyre, '22, General Rate Engineer; Parke D. Appel, '22, General Personnel Assistant; Eugene R. McLaughlin, '19, Division Commercial Supervisor; Thomas H. Barnard, '24, District Plant Engineer; Thomas F. Williams, '22, Metropolitan Traffic Engineer; Kennedy Pope, '20, Massachusetts Transmission Engineer; and Fearing Pratt, '22, Commercial Engineer. Other representatives of the Bell System included George W. Gilman, '23, Director of Systems Engineering for the Bell Telephone Laboratories, and Lawrence B. Grew, '27, and Frank P. Nettleton, '30, of the Southern New England Telephone Company. Among Technology personnel present were: Karl T. Compton, Chairman of the Corporation; Joseph J. Snyder, 2–44, Vice-president and Treasurer; Professor George R. Harrison, Dean of Science; Delbert L. Rhind, Bursar; Professor Carlton E. Tucker, '18, Executive Officer of the Department of Electrical Engineering; Professor Harold L. Hazen, '24, Head of the Department of Electrical Engineering; Mrs. Ruth McG. Lane, Vail Librarian; and Miss Agnes N. Morrice, Chief Operator.

M.I.T. Photos

Below: *Gathered under the portrait of Theodore N. Vail, former president of American Telephone and Telegraph Company, for whom the Institute's library of electrical engineering is named, Professor Harold L. Hazen,'24, Head of the Department of Electrical Engineering (center), recalls the important role which the Vail Library has played in training communications engineers. Others in the group, in usual reading order, are: Dr. Compton, Mr. Harrell, and Erskine N. White and Thomas M. Hennessey, Vice-presidents of New England Telephone and Telegraph Company.*

Above: *Professor Carlton E. Tucker,'18, Executive Officer of the Department of Electrical Engineering; Joe E. Harrell, President of New England Telephone and Telegraph Company; Delbert L. Rhind, M. I. T. Bursar; and Karl T. Compton, Chairman of the M.I.T. Corporation, inspect the new switchboard manned by Miss Agnes N. Morrice, Chief Operator.*

Webster Professorship Established

A GRANT of $400,000 to the Institute from the Edwin Sibley Webster Foundation, to establish an Edwin Sibley Webster Professorship of Electrical Engineering, was announced on January 31 by Karl T. Compton, chairman of the Corporation of the Institute, at the midwinter meeting of Alumni in Metropolitan Boston.

In announcing the new professorship, which becomes the first endowed chair in the Department of Electrical Engineering at M.I.T., Dr. Compton said:

> This endowed professorship is a particularly appropriate memorial to Mr. Webster, for he was one of the earliest students in M.I.T.'s Electrical Engineering Course. He also formed with his classmate, Mr. Charles A. Stone, the first electrical engineering consulting firm, which later became the national organization of Stone and Webster, Inc.

In reviewing Mr. Webster's long and active participation on the Institute's Corporation and its Executive Committee, Dr. Compton pointed out that Mr. Webster exhibited a special interest not only in the Department of Electrical Engineering but in seeing that the Institute moved toward an adequate endowment for its educational program. Dr. Compton also recalled that it was due in large part to Mr. Webster's enthusiasm over aeronautical engineering in its infancy that M.I.T. took its first steps in establishing the first Course in Aeronautical Engineering in the United States. Mr. Webster was president of the Alumni Association in 1909, a member of the Alumni Council, and president of the Class of 1888. The Stone and Webster firm constructed the central group of Institute buildings in Cambridge, and Messrs. Stone and Webster presented to the Institute the President's House.

Commenting on the significance of M.I.T.'s first endowed professorship in electrical engineering, Dr. Compton emphasized that such professorships are a means of fulfilling the primary object of the Institute's long-range Development Program, of giving special distinction to the men who are appointed to them, and of honoring and keeping alive the memory of great men of the Institute.

Two Receive Rhodes Scholarships

RHODES scholarships have recently been awarded to two candidates from M.I.T. – Arthur A. Wasserman, '51, elected in New York, and Carl A. Shiffman, '52, elected in Massachusetts. These recent selections bring to 11 the total number of Rhodes scholars from the Institute, seven of whom have been chosen since the end of World War II, according to Walter H. Stockmayer, '35, Associate Professor of Physical Chemistry and M.I.T. representative for the Rhodes scholarships. From the whole United States 32 scholars are chosen annually.

The complete list of Rhodes scholars to be chosen from M.I.T. is as follows: Morris F. Shaffer, '30, Ivan A. Getting, '33, Walter H. Stockmayer, '35, Vernon G. Lippitt, '38, J. Ross Macdonald, 2–44, Gordon Raisbeck, '49, Eugene B. Skolnikoff, '49, William D. Barcus, Jr., '50, and Herbert D. Benington, '50. In addition, at least three who received Rhodes scholarships were graduate students at the Institute at the time of their selection: Marshall Ballard, Jr., '35, Harry A. Watson, '48, and S. Alton Newton, Jr., '51.

The Institute has good reason to be proud of its record in recent years. In the opinion of Dr. Stockmayer, the enhanced attention which the Institute has given to the humanities has been an important factor in developing the type of man that satisfies the broad requirements of the Rhodes scholarships.

Conciliation

THE first meeting of the Alumni Council for the year 1952 – and the 286th meeting since the formation of the Alumni Association – was held in the Campus Room of the Graduate House on Monday, January 21, with Alfred T. Glassett, '20, President of the Association, presiding.

As first order of business, Donald P. Severance, '38, Alumni Secretary, reported that the Executive Committee had voted to "Authorize the Treasurer to withdraw the sum of $5,000 from the Alumni Association Reserve Fund to meet part of the Institute's capital expense for transferring the alumni mailing lists to an IBM system, an expense now estimated at $8,600." Changes in class affiliations for three Alumni were reported, as was also the fact that between November 26 and January 18, an even dozen members of the Institute's Faculty or staff visited a dozen M.I.T. clubs in a North American loop bounded by Montreal, Portland, Ore., San Francisco, Phoenix, and Atlanta. For the current year, visits through January exceed the total reported at the annual meetings in May of the past few years.

Nominations for officers of the Alumni Association for the coming year, as well as for members to serve on the National Nominating Committee, were reported. Because of its importance to Technology Alumni who will be asked to vote this spring, this topic is covered in a separate story in this section of The Review on page 249.

It was reported that the Executive Committee endorsed the following proposals of George W. McCreery, '19, cochairman of Alumni Day, 1952, as chairmen of Alumni Day subcommittees: *Banquet:* William H. Carlisle, Jr., '28; *Departmental Reunions:* Julius A. Stratton, '23; *Ladies' Events:* Mrs. John B. Wilbur; *Luncheon:* Theodore T. Miller, '22; *Registration:* Wolcott A. Hokanson, Staff; *Transportation:* Emmons J. Whitcomb, '11; *Stein Design:* Henry B. Kane, '24.

As director of the Alumni Fund, Mr. Kane reported that 5,369 Alumni to date have contributed a total of $119,000 to the 1952 Alumni Fund, which is now starting its fourth month. Although this year's change of timing does not permit a real comparison with the figures of the 1949–1950 Fund, these results nonetheless, represent 400 fewer contributors but also show that the amount contributed is $21,000 in excess of the 1949–1950 Fund for the same number of days after the start of solicitation.

Members of the Council were acquainted with recent developments at the Institute by Karl T.

(Concluded on page 254)

BUSINESS IN MOTION

To our Colleagues in American Business . . .

Revere began to make aluminum extruded shapes in 1922, and hence has had thirty years of experience with the metal. During those years it has gained invaluable experience, and has installed new equipment in order to expand the list of aluminum mill products it offers to industry. This expansion has been conducted at an accelerated pace during the past ten years. Today it may come as a surprise to some people that Revere's present installed capacity makes it the largest independent fabricator of aluminum in the United States.

Revere is sometimes asked why we should have sought the same position in aluminum alloys that we occupy in copper and copper-base alloys. The fundamental reason is a simple one: we wished to increase our service to industry, which is demanding more and more metals of every kind. Thirty years ago we recognized the growing importance of aluminum, and we also perceived that aluminum and copper are in many ways complementary metals. Being able to offer both means that Revere can be impartial in recommending the one most certain to give the best results in a given application.

So successful has been our experience with aluminum that we are now pursuing a comprehensive program of expansion in regard to it. In one of the Revere plants in Baltimore, new aluminum rolling mills and annealing furnaces were installed before Korea, making possible tripled production of coiled sheet. Right now, in another Revere Baltimore plant, new extrusion presses and draw benches are being put in place. Equipment for the production of aluminum coiled sheet was installed in our Detroit plant over a year and a half ago. In about a year, the Los Angeles mill, now working with copper and copper-base alloys only, should begin to produce aluminum tube and extruded shapes in both the heat-treated and non-heat-treated alloys.

These plans to increase materially the Revere output of aluminum mill products will make them more quickly and easily available in various industrial centers. Here is evidence of our belief that the future of aluminum is as great as that of copper. Each has its place, in peace as well as war.

Revere's thirty-year growth in aluminum is in the American tradition of freedom to seek new ways to serve customers. It is typical of the business world, for in many thousands of companies the original products or lines have been expanded to include more or less related items. So we suggest that no matter what you buy, you ask your suppliers if they have other materials or products that would be of value to you. The more you know about what your suppliers make, the greater the possibility of improving your products or productivity.

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THE INSTITUTE GAZETTE

(*Concluded from page 252*)

Compton, chairman of the M.I.T. Corporation, who announced the recent promotions of: Professor Harold L. Hazen, '24, who has been in charge of the Department of Electrical Engineering, to succeed John W. M. Bunker as Dean of the Graduate School; Frederick G. Fassett, Jr., newly appointed Associate Dean of Students; and Professor Ernest H. Huntress, '20, as Director of the Summer Session.

President Glassett then called on Mr. Fassett to discuss the operations of the Technology Press and of the Office of Publications – both of which are still under his jurisdiction. He spoke briefly of the genesis of the Technology Press and its more recent 15 years of co-operative publishing with John Wiley and Sons, Inc. of New York.

Mr. Fassett spoke of the need which had brought about the establishment in 1951 of the Office of Publications, an office for the purpose of supervising and expediting the printing of M.I.T. official matter.

Next, Professor Hazen, last summer's chairman of the 15-man Engineering Education Commission to Japan, introduced the final speaker of the evening – Rogers B. Finch, '41, Assistant Professor of Textile Technology.

Professor Finch, who had been the junior member on this Commission organized at the request of the Japanese Ministry of Education, opened his talk by telling of the hospitality of the M.I.T. Association of Japan. In particular he mentioned travel accommodations for his group; the industries they observed; and the Japanese recreations and customs which had come most forcefully to their attention.

Alumni Discuss Weather, Medicine, and Feedback

THE annual midwinter meeting of Alumni of M.I.T. was held in Walker Memorial on January 31. Alfred T. Glassett, '20, President of the Alumni Association, presided at the meeting which was attended by approximately 1,000 Alumni, many of whom brought their sons. As keynote speaker, Karl T. Compton, chairman of the Corporation, reported to the Alumni on recent developments at the Institute, and announced a grant of $400,000 for the establishment of the Edwin Sibley Webster Professorship of Electrical Engineering.

Professor George R. Harrison, Dean of Science at M.I.T., was master of ceremonies for three lectures given by members of the Institute's Faculty: James M. Austin, '41, Associate Professor of Meteorology, described modern methods of weather forecasting; Professor Francis O. Schmitt, Head of the Department of Biology, discussed medical research at the Institute, with emphasis on the significance of the electron microscope in this research; and Professor Gordon S. Brown, '31, Associate Head of the Department of Electrical Engineering and chairman of the Faculty, spoke on the growing importance of servomechanisms in industrial progress.

WHITHER CIVIL ENGINEERING?

(*Continued from page 239*)

D.W.T. What do you mean? You've got the old-fashioned point of view on foundation engineering – taking the soil as you find it and limiting the structure to fit. They don't do that any more.

T.W.L. I should say not. If the soil isn't the kind they want, they treat it chemically, and change its properties – increase its bearing capacity, its impermeability, or anything else.

H.P.A. Take that earth dam, for example: the cutoff wall is a thin membrane of impervious chemically treated clay, and the side slopes are steep because the shearing strength and the angle of repose of earth have been increased.

T.W.L. That building is settling up instead of down! Must have given the foundation an overdose!

W.M.F. They seem to have gotten away from the more conventional building shapes. The structural engineers must be building their structures around the activities that are actually going on in the building. They're more functional, and certainly are more clean-cut and streamlined.

E.M. You'd think that with all those curves, their unit building costs would be up.

M.J.H. Standard shapes, prefabrication, and mechanization of construction – that's the answer. That new concrete hospital is an all "prefab" job. And look at the erection of that row of six-story apartment houses; it's all being done from one gigantic overhead gantry crane that moves from block to block.

J.M.B. That new TV tower must be 2,000 feet high!

W.M.F. And that trestle for the rocket ships!

A.T.G. And that inverse membrane dam!

C.H.N. And that weird-looking building for the atomic-energy plant!

A.T.I. And that floating service island for the transatlantic hydrofoil ships!

A.J.B. And that vehicular tunnel under the English Channel!

J.B.B. All I can say is that I'm glad somebody else will be placement adviser by then!

It will be seen that structural engineering had kept apace of the demands of construction, both within and beyond the scope of the civil engineering field. Better methods of analysis and design, ingenious new structural layouts, better use of existing materials, and the almost complete mechanization of prefabrication and erection had all played their part in reducing construction costs, and this, of course, was of utmost importance, since it meant that more structures could be built with the money that was available. But perhaps the most spectacular advances had come about as a result of the introduction of new and usually synthesized construction materials, once again demonstrating the vital role of basic research in civil engineering progress.

(*Continued on page 256*)

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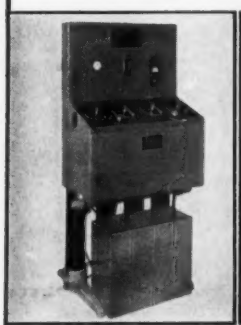
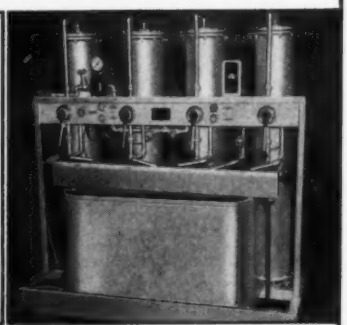
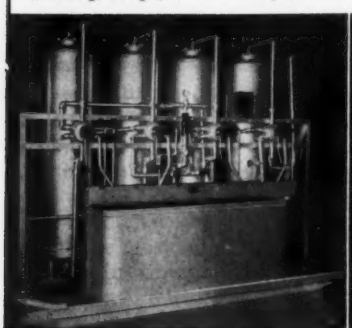


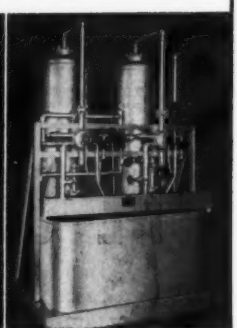
Barnstead Four-Bed Demineralizer provides pure water for hot seal tank in anodizing. 30 gal/h.



Four-bed Barnstead Demineralizer produces pure, sparkling-clear rinse water for pharmaceutical plant. 200 gal/h.



Four-bed Barnstead Demineralizer providing pure, high resistance water for electronic mfgr. 1000 gal/h.



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WHITHER CIVIL ENGINEERING?

(*Continued from page 254*)

The relatively small number of bombproof buildings in existence was especially noteworthy, for it appeared that atomic warfare was no longer a major consideration. While other factors had been of utmost importance in bringing about this happy condition, the contribution of the civil engineer was not to be minimized. Hydraulic engineers had done much to increase the power and food supply of the world; sanitary engineers had played an important part in improving the environment in which people lived; transportation engineers had helped to distribute the goods of the world; while structural and foundation engineers, as the servants of the other three, had done their share by building the structures that made these things possible. All of these activities had contributed directly to a higher standard of living throughout the world, and thus had helped to remove one of the major causes of war.

And now I want to speak to you with complete seriousness. This is not to say that there has been no serious thought behind my previous remarks, for I have tried to give you a picture not only of what civil engineers do today, but of what the trends are likely to be in the future. Though my method of presentation has doubtless led me into pitfalls, I have tried to keep the over-all impressions that I hope

(*Continued on page 258*)

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TEST #1 AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY

AMP terminal connections (which had been subjected to salt spray) were placed in series with the input of a high gain, wide band pass amplifier (originally developed for checking thermal noise in R.F. input circuits). Dr. Wiesner's results, after testing AMP terminals, substantiate "the unlikelihood that metal-to-metal contact as it exists in crimped solderless connections would be expected to develop noise"

TEST #2 AT AN ARMED FORCES TEST LAB

Since a terminal has but a few milliohms resistance, this test required a special transformer to match this low impedance to the input of the amplifier, sensitive to levels of 0.2 micro volt. 60 AMP solderless terminals crimped to short lengths of wire in series, a similar number of carefully soldered joints, and a single piece of solid wire of equivalent R, were compared.

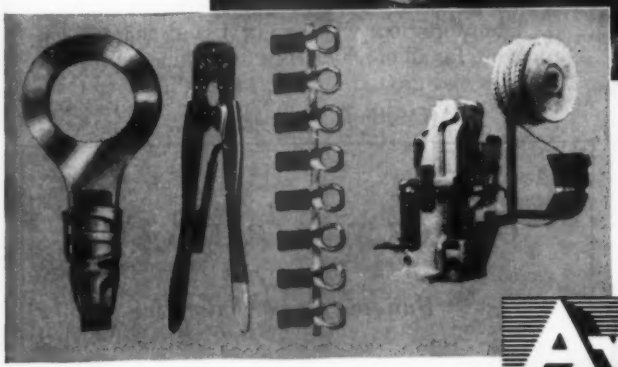
No noise difference was detectable between any of the three.

TEST #3 AT A PROMINENT UNIVERSITY LAB

7,000 AMP solderless connectors were crimped to short lengths of wire in series making a chain of terminals 340 feet long (see illustration). After aging for two years in an unfavorable atmosphere these 14,000 connections in series were tested at radio frequencies up to 20 megacycles.

AGAIN—Noise measurements were down to thermal magnitude.

(Copies of all test results available on request to our ELECTRONIC DIVISION.)



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WHITHER CIVIL ENGINEERING?

(*Continued from page 256*)

to leave with you in line with an attempt to appraise the future of civil engineering in a serious manner. I hope that the net result has been of interest to all of you and particularly to the first year civil-engineering students who are here tonight.

If, among the latter, there are some who are still uncertain as to their final course selection, I would like to say to them: In choosing your course the most important question to ask yourself, in my opinion, is: Would I like that kind of work? Would I find it interesting? Because if you like doing something, you will do it successfully, and even more important, you will be happy doing it. Conversely, if you get into a field that you don't enjoy, you can't do a really good job, regardless of how hard you try. Of course there are other considerations, for what will happen to you in the profession you choose, depends on many things. If I may quote from Ecclesiastes IX:11: ". . . the race is not always to the swift, nor the battle to the strong, neither yet bread to the wise, nor yet riches to men of understanding, nor yet favour to men of skill; but time and chance happeneth to them all." You cannot tell what will have happened by 25, or 10, or even one year from now, but you do have some basis for knowing what kind of work you will find interesting, and to some degree, even exciting. If the work you are in can make you wake up in the morning, eager to meet the challenge of the new day; your future, though affected by time and chance, has every prospect of being a source of continuing satisfaction.

And to all of you, I would like to say: When you analyze what I've said tonight about the future of civil engineering – when you consider the different areas of civil engineering that I've discussed – there are certain ideas, certain common denominators, that come up again and again. These are so important that I shall conclude my remarks by pointing out just four of them:

1. Transportation, water control, and suitable environment, for all of which the civil engineer provides structures and ground facilities, underlie every thea-

(*Continued on page 260*)

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What GENERAL ELECTRIC People Are Saying

I. LANGMUIR

Research Laboratory

PLANNING UNPLANNED RESEARCH: You can't plan to make discoveries. But you can plan work that will probably lead to discoveries.

Dr. Willis Whitney discovered a word which is in the dictionary—serendipity—and I don't like the definition that is given. Let me suggest this one: "The art of profiting from unexpected occurrences." Now, it seems to me a large part of the Laboratory work is based on that. You don't know all the things that are going to happen; too many of them are unexpected. But it is these unexpected things that are going to be the most profitable—the most useful—things you do.

In 1942, when I was President of the American Association for the Advancement of Science, I broadcast a half-hour talk in which I said that physics nowadays is not like the physics of the past century. There is classical physics, and there is quantum mechanics. What's the main difference?

The old idea of physics was that everything was perfectly, definitely due to causality. There was a definite relation of cause and effect. And that worked perfectly well in classical physics. But, then, years later came the quantum theory and the uncertainty principle of Heisenberg. But Bohr, five or ten years before Heisenberg's uncertainty principle, had the idea of the correspondence and uncertainty principles very clearly in mind. I remember Bohr saying that if a thirteen inch shell is coming toward you, several thousand feet a second —headed right toward you—it may pass through you and produce no effect whatever. There is a certain definite chance that this will happen —very small.

Take another example. You can see the track of an alpha particle. It's one quantum effect—a radium atom exploded. Fundamentally, you can't find the cause for such things. In fact, as Bohr pointed out very clearly, if you could find out what it is that sets off a radium atom after 2000 years, then the whole of quantum mechanics would have to go by the board. It's basic that those must be the fundamental things, the probability, and not the cause of the definite action. All right, if an alpha particle can leave a track and a man can do something as a result of it—see it, for example—he may either get killed or not get killed because of timing. He may be run over by an automobile because he left his office a little later than he otherwise would have.

So single quantum effects can affect the lives of individuals. Now, the moment you prove that in principle, the whole basic idea of cause and effect is gone for all those phenomena that can be started from small beginnings and grow up to large things.

Take heredity, for instance. A single gene cell can be affected by a cosmic ray or by x-rays. Single quantum phenomena. They're absolutely interminable. And, therefore, basically the whole development of the human race has not been the result of cause and effect—only probabilities.

Come down to human affairs—an idea, for instance. How did it begin? Why, with something as small as a quantum, or the actions of a lot of separate quantums, of course. You have the dividing of the ways. Either you do one thing or the other. You continue to have alternatives. Those alternatives may determine things of tremendous importance.

If you can't predict ideas, you can't plan things in a laboratory. But you can organize a laboratory so as to increase the probabilities that useful things will happen there. And, in so doing, keep the flexibility, keep the freedom. That's what freedom is for. All of us in this Research Laboratory are interested in freedom. We know from our own experience that in true freedom we can do things that could never be done through planning. That's why we are going to beat out Russia in the long run.

Stalin believes that everything can be planned. Marx believed that everything could be planned. That's the trouble with all dictators. They think that they can run the world by planning from above. And that is an utter impossibility, basically and fundamentally, because of the existence of divergent phenomena.

The moment that you see that the world isn't a kind of place where complete planning is possible, then you believe in democracy, you believe in freedom and initiative—in all the kinds of things that can be planned only in very general ways, not in detail.

What did Mussolini try to do? What did Hitler try to do? They had plans for conquering the world, and they knew just how to do it. They failed. They failed for many reasons, but one of the reasons is that you can't run things that way. And I think, no matter how far you may go in dictatorship, no matter how far it may succeed, it will ultimately fail because of the impossibility of planning on a world-wide scale.

Now, in this Laboratory we have a good example. I think most of us here have ideas of freedom and of the importance of thinking things out in our own way. Human virtues such as curiosity, initiative, interest in things, and just doing things for the fun of it, add up to me as just one of the things you realize in this Laboratory. And if only it could be that way on a world-wide scale, we would be much better off than we are now.

Colloquium
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WHITHER CIVIL ENGINEERING?

(Continued from page 258)

ter of human activity. Essential as they are today, they will be needed even more vitally as civilization becomes more complex.

2. The birth of each new branch of engineering creates new opportunities for the civil engineer: for example, aeronautical engineering has made the airport necessary; mechanical engineering has led to our traffic problems; chemical engineering has created many of our problems of stream pollution.

3. Each advance in another field of engineering or in science leads to new ideas and new tools that help to advance the field of civil engineering: for example, aerodynamics has stimulated hydraulics; colloidal chemistry is helping soil mechanics; the development of electronics has aided in instrumentation for civil-engineering research.

4. The keys to the future of civil engineering are threefold: (first) A growing awareness of social and economic values, leading to sounder planning; (second) A growing emphasis on fundamentval research, leading to better design, and (third) The wiser management of men and equipment, leading to better methods of construction. But of these three keys, research is the most important, for it is only by extending the boundaries of knowledge that a profession not only maintains its stature, but forges its way to the new frontiers that always lie ahead.

Reference Key

Alphabetical list of names and titles of members of M.I.T. Department of Civil and Sanitary Engineering identified by initials in foregoing article.

H.P.A. – Harl P. Aldrich, Jr., Assistant Professor of Soil Mechanics.

J.B.B. – John B. Babcock, 3d, Professor of Railway Engineering.

J.M.B. – John M. Biggs, Assistant Professor of Structural Engineering.

A.J.B. – Alexander J. Bone, Associate Professor of Highway and Airport Engineering.

J.W.D. – James W. Daily, Associate Professor of Hydraulics.

R.E. – Rolf Eliassen, Professor of Sanitary Engineering.

(Concluded on page 262)

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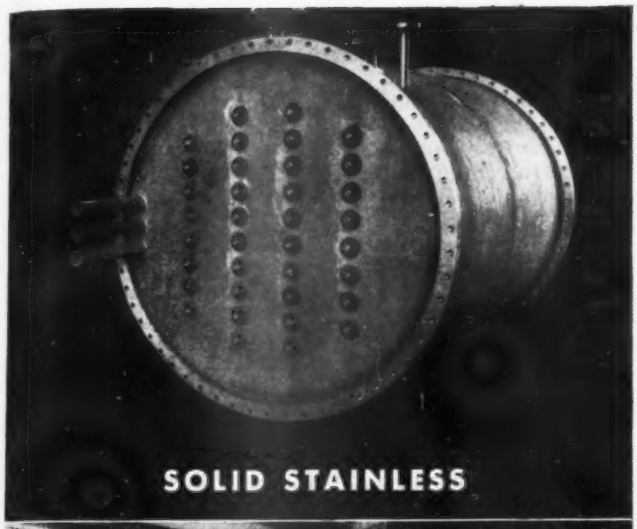

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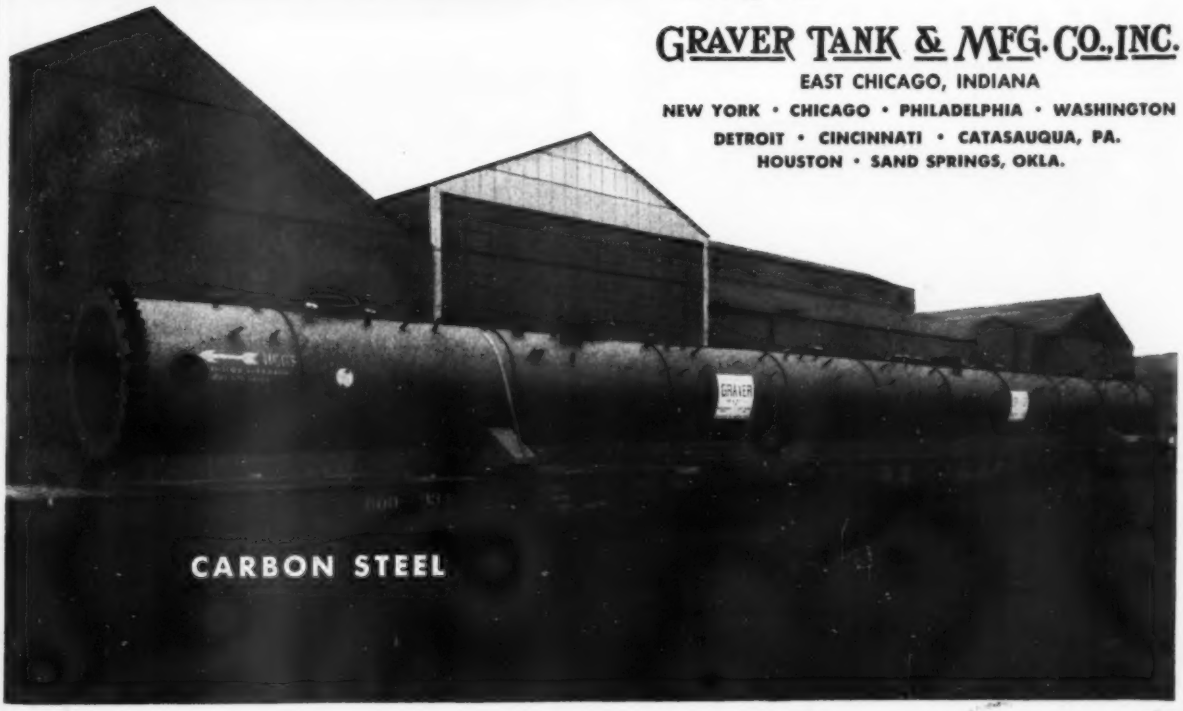

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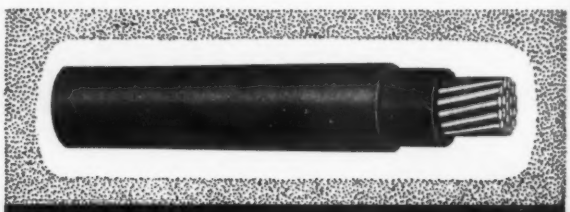

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CONDUCTOR Gauge Size	Strands	Resistance Per M ft. at 400° F.	Current Rating*	SRHT(NN) (GN) (CV) or (GV) Outside Diameter ± .005″	Copper Wgt. Lbs/M′	Net Wgt. Lbs/M′	List Price Per C′	Shielded SRHT(GS) Copper Wgt. Lbs/M′	Net Wgt. Lbs/M′	List Price Per C′
26	12	85	.8	.040″	.9	2	$ 7.00	5	6	$ 8.50
24	7	45	1.5	.050″	1.4	2.5	7.00	6	7	8.60
24	19	45	1.5	.050″	1.4	2.5	8.00	6	7	9.60
22	7	28	6.	.060″	2.2	3.5	7.50	7	9	9.20
22	19	28	6.	.060″	2.2	3.5	8.00	7	9	9.70
20	7	17	10.	.070″	3.5	5.0	8.00	10	12	9.80
20	19	17	10.	.070″	3.5	5.0	8.50	10	12	10.30
18	7	11	15.	.080″	5.6	7.5	8.50	14	17	10.50
18	19	11	15.	.080″	5.6	7.5	9.00	14	17	11.00
16	19	8.1	27.	.090″	8.8	11.0	10.00	17	20	12.10
16	41	8.1	20.	.090″	8.8	11.0	11.00	17	20	13.00
14	19	5.1	27.	.105″	13.7	16.	13.00	22	28	15.40
12	19	3.2	37.	.135″	21.8	26.	17.00	30	36	20.00
10	37	1.9	50.	.150″	34.5	40.	20.00	46	51	23.20
8	133	1.1	67.	.200″	55.	60.	26.50	68	74	30.00
6	133	.74	91.	.240″	84.	92.	32.00	97	107	36.00

* Based on single conductor in free air at 220° F. ambient temperature.

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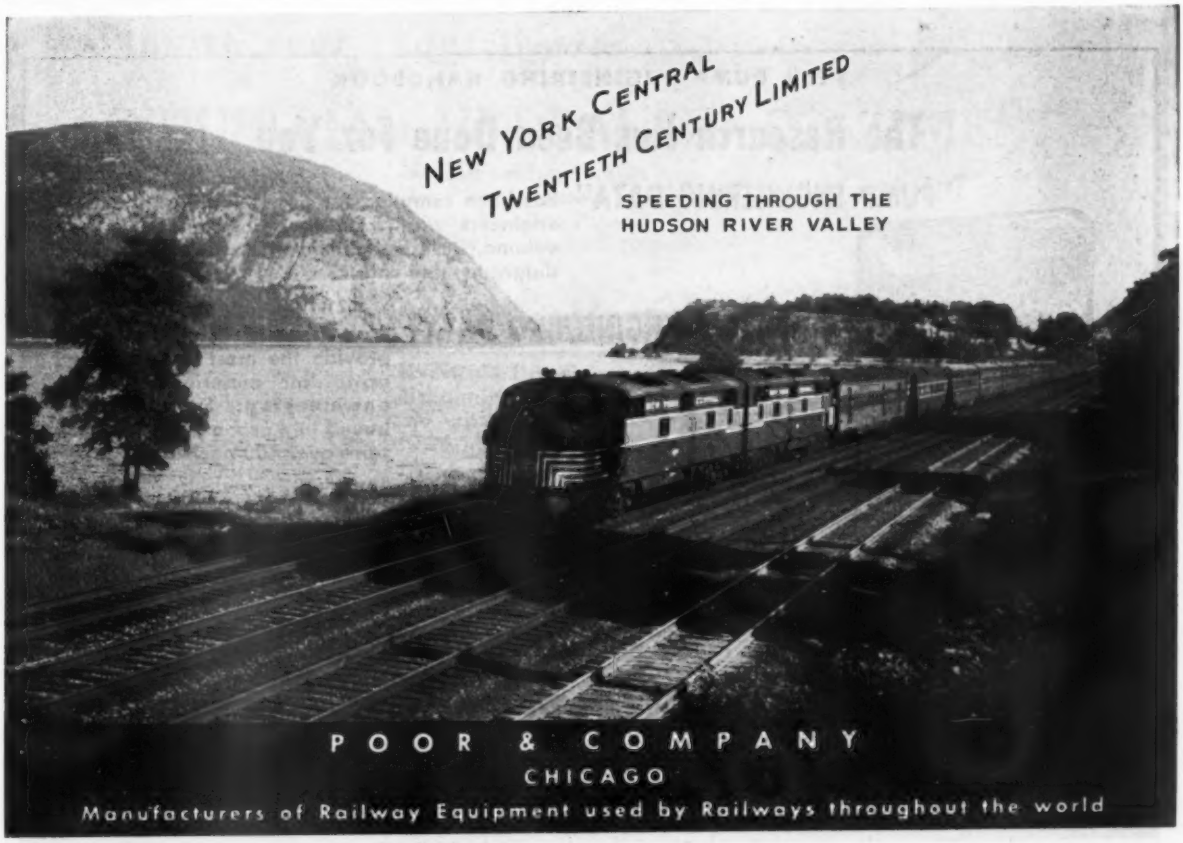

RENAISSANCE IN METAL CUTTING

(Continued from page 247)

Other more conventional testing techniques, such as microhardness determinations, true stress-strain tests for workpiece materials, and the preparation of photomicrographs to establish metallographic structure are of a considerable value in metal-cutting studies. Fig. 5 shows a special application of the standard photomicrographic technique that is very useful in studying the nature of the roughness of finely finished surfaces. In this case a ground surface is plated and then sectioned by a plane that makes a small angle with the original surface. When the sectioning plane is polished and etched and observed through the microscope, a picture such as that of Fig. 5 is obtained. This method provides a view of the surface that conveniently has different magnifications in the two directions. The individual grooves that were left by the grinding grits in producing this surface are seen to be about 50 microinches deep and about 750 microinches wide.

The x-ray diffraction camera is one of the less familiar, conventional test methods that has been recently used in metal-cutting studies. Pictures, such as those shown in Fig. 6 are produced by causing an x-ray beam to be refracted from a metal surface and then onto a photographic plate. When the specimen is in the annealed condition, the refraction pattern will consist of sharply defined circular arcs as shown in Fig. 6, but when the surface is cold worked, as by grinding, the refraction pattern is diffuse. By progressively etching layers from a ground surface and taking x-ray pictures of the surface thus uncovered, the depth of the cold-worked layer that is produced by a machining operation may be determined.

As is evident in the foregoing brief discussion of some of the research methods that are now employed in fundamental metal-cutting studies, many techniques and concepts have been drawn upon from other fields of endeavor. However, metal-cutting research is also extending its influence into apparently unassociated areas. For example, the organic chemist is now utilizing the results of a fundamental study of cutting fluid action to synthesize chemicals more effectively. In one very important type of reaction, metallic magnesium is reacted chemically with halides to produce valuable and versatile intermediates known as Grignard reagents, after their inventor. Glass apparatus, such as that shown in Fig. 7, is the conventional means for carrying out such reactions. Obviously this is a batch-type, small-scale operation and it is quite hazardous, too, inasmuch as the reaction must be carried out in the presence of large quantities of inflammable ethyl ether. Apparatus similar to that shown in Fig. 8 is now used to cut magnesium in the presence of the liquid reactants. Due to the very high pressures and temperatures obtained at the cutting point and the continuous generation of nascent, oxide-free surface,

(Continued on page 266)

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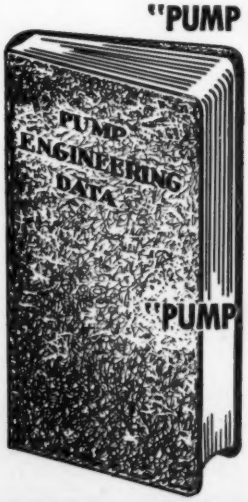

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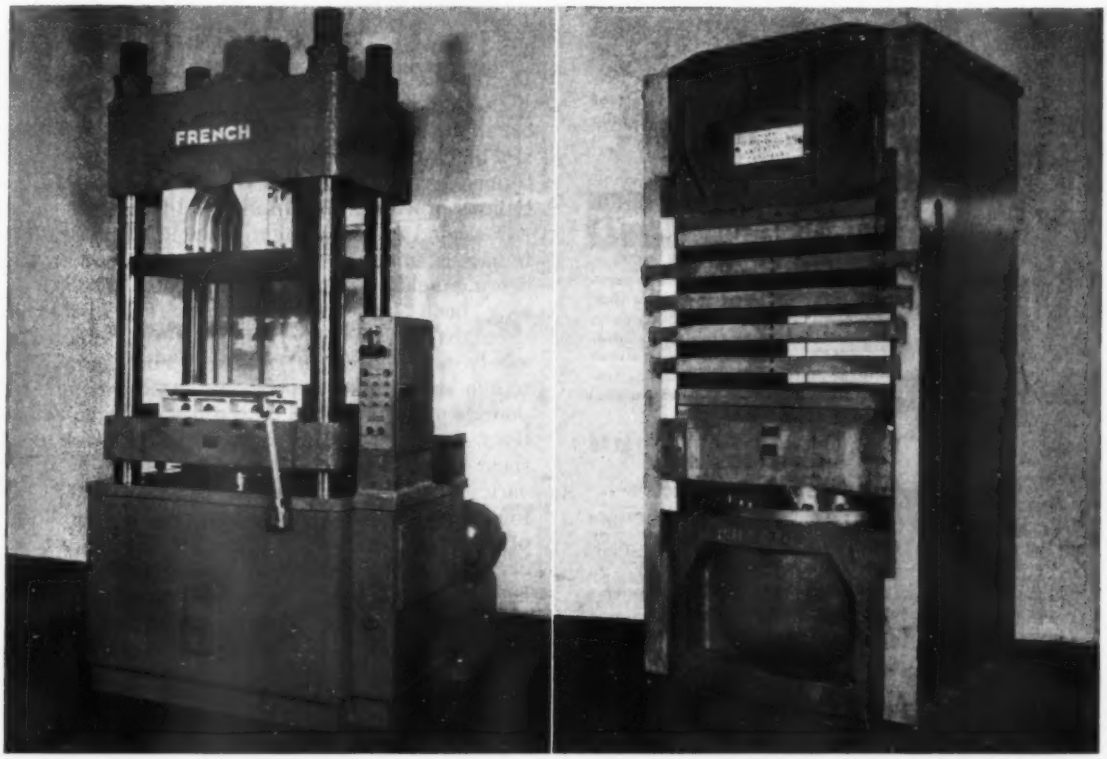

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RENAISSANCE IN METAL CUTTING

(Continued from page 264)

the reaction can be made to go forward continuously with no induction period. The new process has been called mechanical activation. The once hazardous and batch-type Grignard process has now been transformed from a laboratory curiosity into a safe continuous process with an industrial future.

A second example might be cited to illustrate the impact of metal-cutting research on another engineering field. From physicists' calculations it has long been suspected that metals should exhibit strengths that are many times greater than those commonly experienced in practice. For example, the tensile strength of steel should be about 4,000,000 pounds per square inch on the basis of such calculations. In metal cutting, a pronounced effect on the shear stress has been observed as depth of cut varies. The flow stress on the shear plane has been found to increase significantly with decreased depth of cut. However, this increase in stress ceases at a certain depth of cut of about 30 microinches, which is the depth of cut obtaining in a fine grinding operation. At this point the shear stress appears to be close to 2,000,000 pounds per square inch (which is in good agreement with the aforementioned theoretical tensile value of 4,000,000 pounds per square inch according to the maximum shear theory). The explanation for the huge difference between the strength of a very small specimen and one the size of ordinary structures is simply that all metals contain flaws, and the probability of a flaw being present in a given specimen decreases as the specimen size is reduced. Strangely enough, the long-sought-for critical experiment to demonstrate the existence of a theoretical strength for metals and a size effect has apparently been found unexpectedly in the grinding operation, where a materials test may be performed on a specimen that is phenomenally small (corresponding to a tensile test specimen of less than 30 microinches in diameter).

Getting Results to Industry

The gathering of experimental data and its interpretation is not the sole problem of an engineering research laboratory. The job is only half completed at this stage. The knowledge developed during the experimental phase must get into the hands of those

(Concluded on page 268)

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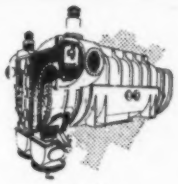

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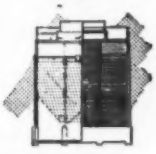

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RENAISSANCE IN METAL CUTTING

(Concluded from page 266)

who can put it to use before an engineering research investigation may be considered to be successfully completed. New material must quickly find its way into the teaching program and also be made available to industrial workers. The task of introducing new ideas and concepts into the teaching program is best accomplished by having those engaged in teaching simultaneously engaged in a vigorous research program. The problem of disseminating research findings to persons in industry is not easily accomplished but at M.I.T. this is being achieved:

1. Through publications in the technical press and public lectures;

2. Through special intensive summer programs. Last summer three such programs, each of two weeks' duration and designed to be of interest to machine-tool people, were presented at M.I.T., embracing the following topics: metal cutting, lubrication, and hydraulic controls;

3. By making available to industry well-trained graduate and undergraduate students who are thoroughly familiar with current developments in metal-cutting research. This is probably the most effective means of establishing the all important liaison between the academic laboratory and industry, but requires a relatively long time for fruition;

4. By direct consultation.

Conclusion

The fact that an art as old as metal cutting should have progressed so little in the direction of a science is most discouraging. However, some encouragment is to be found in the fact that it was less than 15 years ago that the first attempts were made, by Viano Piispanen, a Finnish engineer, to attack this problem from the standpoint of analytical mechanics. A great deal of progress has been made since that time. If the metal-cutting industry continues to support the fundamental studies now under way, and continues to express a patient and sympathetic attitude toward the efforts being extended, the renaissance in metal cutting may well be completed in a short time. It will then be possible to attack a metal-cutting problem on the same rational basis as is now commonplace in the fields of power-machinery design, hydraulics, and metallurgy.

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STEPBROTHER TO THE IRON HORSE

(*Continued from page 244*)

A car that could be used throughout the entire year, in place of the duplicate complement of open and closed cars, had been the subject of many experiments. The rising costs of the World War I period forced the adoption of such cars, known as "semi-convertibles," because of the large windows that could be opened wide for summer comfort. Increased costs were also largely responsible for a totally new design of car — the Birney safety car.

From the start the Birney safety car was designed to be operated safely by one man. It contained such safety devices as the dead-man control (which would bring the car to a safe stop if the motor controls were unattended) and the doors interlocked with the air brakes. The body had rather light steel subframe, window posts, roof arches, and side panels, but the floor, roof deck, doors and sash were of wood. The running gear was a new type of single truck with two 25-horsepower motors.

About this time the private automobile and the bus began to be major factors in local transportation. Henry Ford had achieved quantity production of his "Tin Lizzy" by 1910; and the gasoline engine had demonstrated that it had been made reasonably reliable. Paved roads were being extended. The biggest remaining difficulty was with tires. At the beginning of World War I a Ford tire cost more than $30 and could be used for possibly 4,000 miles. Punctures and blowouts were frequent so that every trip became an adventure, with arrival time highly uncertain. Trucks and busses ran on solid rubber tires which combined reliability with a barely acceptable minimum of cushioning.

During World War I, tire manufacturers happened to try carbon black as a substitute for unobtainable filler materials in their rubber mix. They were surprised to find that the result was an abrasion-resistant material which was ideal for tire treads, at least doubling the life and greatly reducing punctures and blowouts. Meanwhile, automobile production was multiplying and prices were dropping. From 1908 to 1910, Ford made perhaps 8,000 cars selling at more than $900 apiece; a dozen years later he made more than 1,000,000 cars a year and the price was about half as much.

As a result the farmer bought a "flivver" to take him to town, instead of the slow horse and buggy or the infrequent trolley. The city dweller bought a home in the country and relied on his car to take him to work. The workman took a Sunday drive instead of a trolley ride. Wildcat operators started jitney-bus lines in direct competition with the trolley routes. The majority of trolley companies went into receivership and a substantial mileage of line was abandoned and dismantled. Among the abandonments was the Needham-Wellesley line mentioned in the 1914 trip. By 1916 this line was taking in $0.18 per car-mile, but

(*Continued on page 272*)

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The data presented below summarize the Fund's transactions during 1951 together with cumulative figures for the past twenty years.

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ITEMS OF OUTGO:			
Number of Men Receiving Loans	3,382	3,144	up 238
Total Amount Loaned	$2,435,025	$2,253,879	up $181,146
Average Per Capita Loan	$ 720	$ 717	up $ 3
ITEMS OF INCOME:			
Number of Men Whose Indebtedness has been Completely Discharged	2,357	2,279	up 78
Principal Repayments in Advance	$ 618,078	$ 601,914	up $ 16,164
Other Principal Repayments	$1,232,765	$1,176,223	up $ 56,542
Total Principal Repayments	$1,850,843	$1,778,137	up $ 72,706
Total Principal Matured, Considering "Advance Repayments" as Matured, when Paid	$1,882,891	$1,810,287	up $ 72,604
Collection Ratio, i.e. Percentage of Total Maturities Paid	98.3	98.2	up 0.1
Matured Principal in Arrears	$ 22,679	$ 23,390	down $ 711
Actual "Written Off" Accounts	$ 9,370	$ 8,760	up $ 610
Total Maturities Unpaid	$ 32,049	$ 32,150	down $ 101
Percentage "Written Off" to Total Loans	0.38	0.38	
Percentage Matured Loans in Arrears plus Amount "Written Off" to Total Loans	1.32	1.43	down 0.11
Interest Received	$ 236,891	$ 231,855	up $ 5,036
Times Interest Received to Matured Loans in Arrears plus Amount "Written Off"	7.4	7.2	up 0.2
NOTES OUTSTANDING	$ 574,812	$ 466,982	up $107,830

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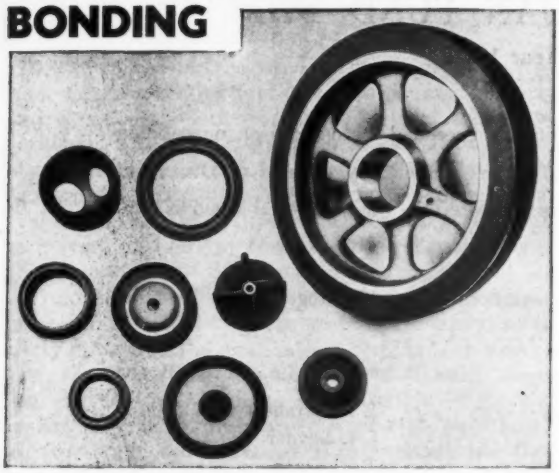

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STEPBROTHER TO THE IRON HORSE

(*Continued from page 270*)

its operating costs came to $0.27. A one-man Birney safety car was ordered for the line, but in 1918 there came a strike and resulting increase of operating costs, so the line was abandoned.

In the early 1920's, several truck manufacturers introduced "streetcar type" busses with seats, doors, fare registers, and body details very similar to current models of trolleys. They seated from 25 to 30 passengers, and they were equipped with pneumatic tires, and sometimes with air brakes. Street railway companies tried these new vehicles for route extensions, and as a substitute for cars on lines where the track was worn out and traffic was too light to justify replacing it. They proved highly successful and bus substitutions for trolley cars steadily multiplied.

But the trolley car put up a good fight. The Birney safety car proved to be too small for most lines, and its single truck made its riding qualities poor. Double truck cars, which kept the one-man operation and the lightweight steel construction of the Birney, were designed and built in large numbers in the 1920's. The Boston Elevated Railway, for example, adopted a design seating 48, weighing 15 tons, and powered with four 25-horsepower motors. This car would do substantially the same work as a 1911 design seating 52, weighing 26 tons, and powered with four 50-horsepower motors. Furthermore, the newer designs were more economical in power consumption and track wear than their prototype of a decade earlier. Where riding was heavy the large seating and standing capacity made such cars less expensive to operate than a bus. As for capital cost, a car cost about as much, per seat, as a bus. Offsetting the large capital investment in track, wire, and power plant was the much longer life of cars: track would last a good 20 years, and cars at least 30. Early busses were considered good for five years; today seven to 10 years is the usual estimate.

In the early 1930's, a group of transit executives, called the President's Conference Committee, initiated a project that led to the development of the streamline trolleys seen in many cities today. These cars were introduced commercially in 1936, and now some 2,000 are in service. Four 55-horsepower motors (about twice the power-to-weight ratio of previous cars) give extremely high acceleration, and the mo-

(*Concluded on page 274*)

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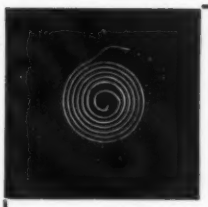

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STEPBROTHER TO THE IRON HORSE

(*Concluded from page 272*)

tors are also used for smooth dynamic braking. The resistance of the starting box for both acceleration and braking has a large number of steps to eliminate jerk. Hypoid-gear drives and rubber-bodied wheels greatly reduce noise. Streamline styling, cushioned seats, foot-operated controls, windshield wipers, stop lights, and sealed-beam headlights were adopted from current automotive design.

But despite these many modern improvements, the trolley car is fighting a losing battle. Its troubles are largely economic. Busses have been enlarged and improved to handle heavy riding. Trolley busses, which combine maneuverability and curb loading with the economy of central station power, are successful in many places. When trolley cars, rather than busses, are involved, traffic jams at least seem worse for both transit passengers and private automobiles. But the decline of the electric street railway is also partly a matter of style. The automobile has captured the popular imagination as the railroad did a century earlier, and every member in the family of the iron horse is having tough going.

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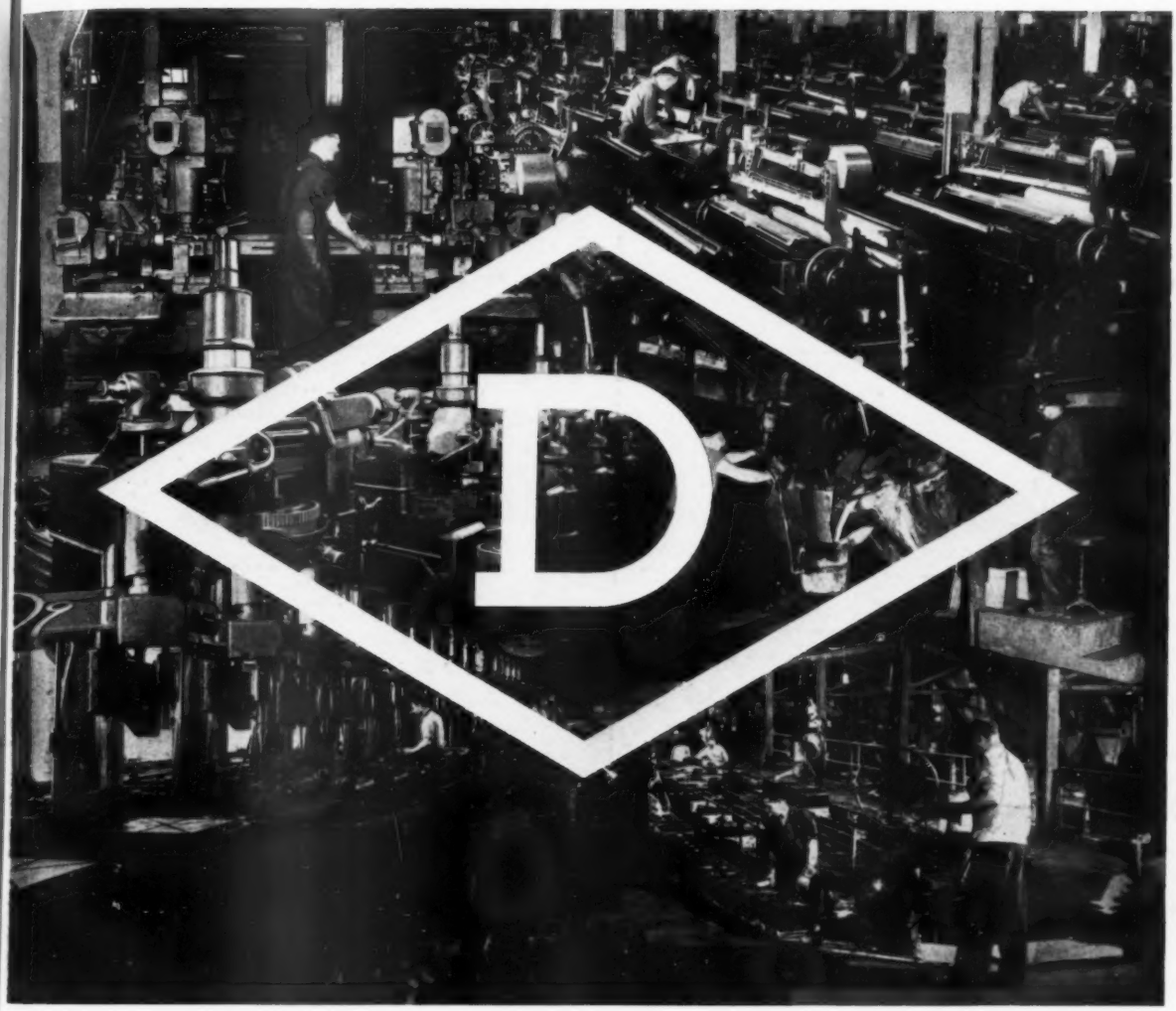

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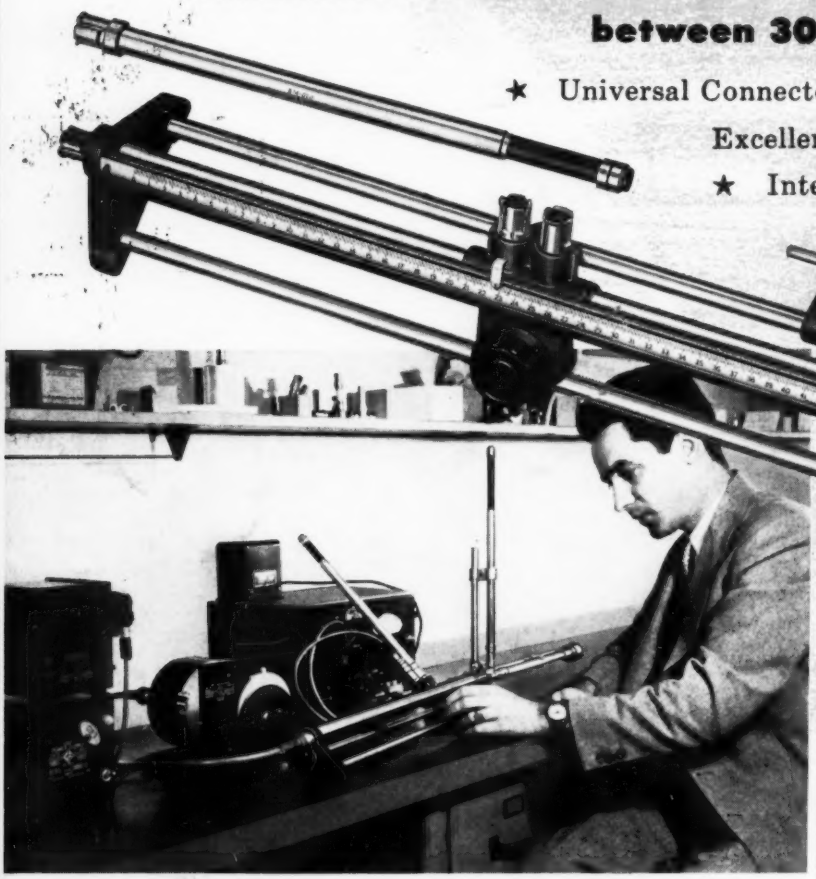

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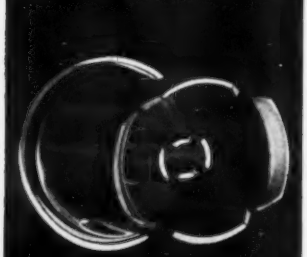

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